SEWAGE AND INDUSTRIAL WASTES

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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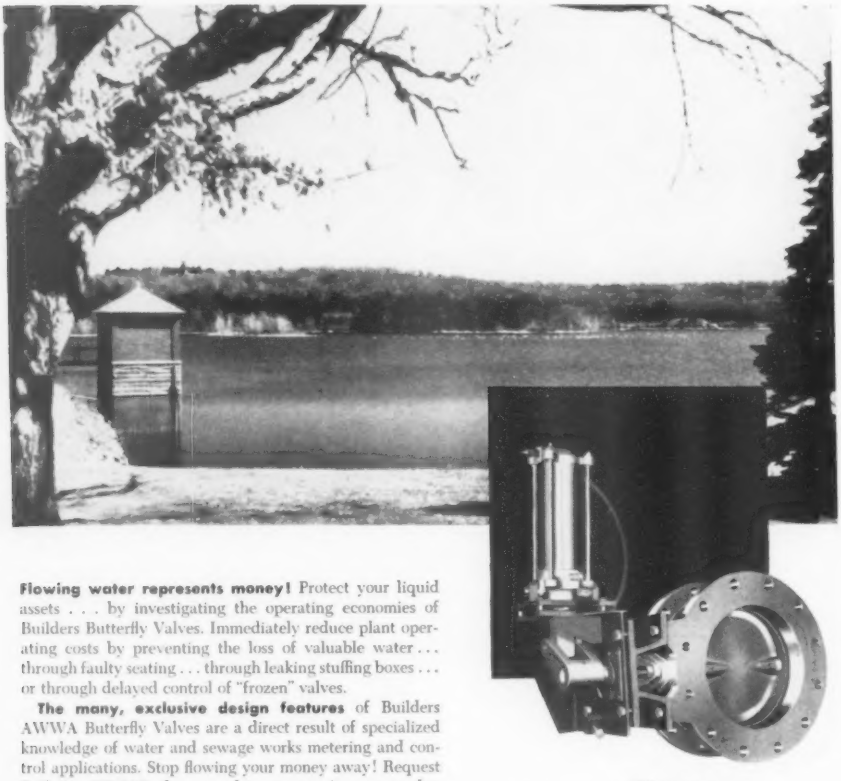

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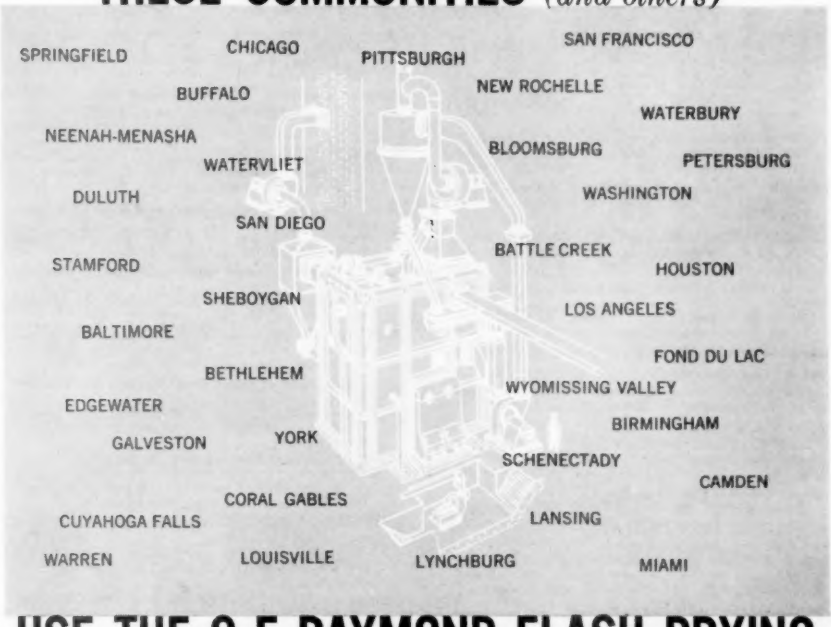

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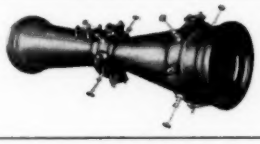
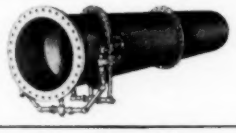
NORMAL SEWAGE, SLUDGE, TRADE WASTES		TYPE VS—FOUR TAP VENTURI TUBES Four cleaning valves at main and throat can be operated manually, by air, or hydraulically to keep piezometer holes clear for top accuracy. Two hand holes on each pressure belt and inspection opening at throat. BULLETIN 005
LOW-VELOCITY SEWAGE, HEAVY WASTES		TYPE VE—ELLIPTICAL VENTURI TUBES Developed specifically to accurately measure low-velocity sewage, sludge and heavy trade wastes—under low pressures. *Flat top* prevents air binding. *Flat bottom* is self-scouring. Inspection opening at throat. BROCHURE
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Iowa Sewage and Industrial Wastes Assn.	Hotel Chieftan Council Bluffs, Iowa	June 18–20, 1958
Michigan Sewage and Industrial Wastes Assn.	Charlevoix Hotel Charlevoix, Mich.	June 23–25, 1958
Institute of Sewage Purification	Floral Hall Southport, England	June 24–27, 1958
Pennsylvania Sewage and Industrial Wastes Assn.	Penn. State Univ. University Park, Pa.	Aug. 13–15, 1958
Georgia Water and Sewage Assn.	Ga. Inst. of Tech. Atlanta, Ga.	Sept. 10–12, 1958
Rocky Mountain Sewage and Industrial Wastes Assn.	Cosmopolitan Hotel Denver, Colo.	Sept. 15–17, 1958
South Dakota Water and Sewage Works Conf.	Franklin Hotel Deadwood, S. Dak.	Sept. 17–19, 1958
Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.	Hotel Peabody Memphis, Tenn.	Sept. 22–24, 1958
Oklahoma Water, Sewage and Industrial Wastes Conf. (Short Course)	A and M College Stillwater, Okla.	Sept. 24–25, 1958
Pacific Northwest Sewage and Industrial Wastes Assn.	Davenport Hotel Spokane, Wash.	Sept. 25–27, 1958
Missouri Water and Sewerage Conf.	Hotel Governor Jefferson City, Mo.	Sept. 28–30, 1958

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Sheraton-Cadillac Hotel, Detroit, Michigan
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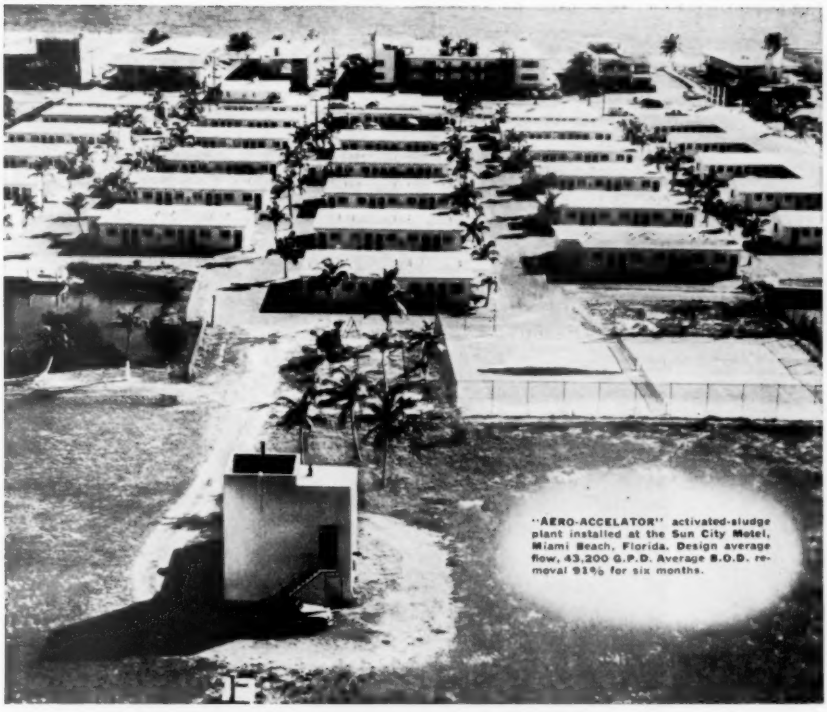

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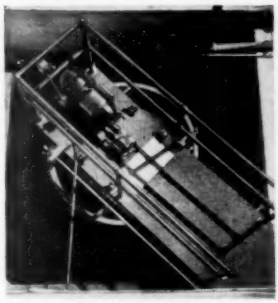
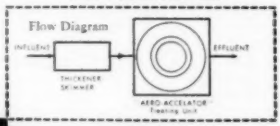
		Raw Sewage	"AERO-ACCELATOR" Effluent	% Removal	Raw Sewage	"AERO-ACCELATOR" Effluent	% Removal
Jan.	.006	187	9.5	94	239	24	90
Feb.	.010	157	13.0	92	409	32	92
Mar.	.005	137	7.0	95	383	28	93
Apr.	.006	211	25.0	88	328	38	89
May	.006	171	9.9	94	222	5	97
June	.008	173	8.8	95	295	32	89



"AERO-ACCELATOR" unit



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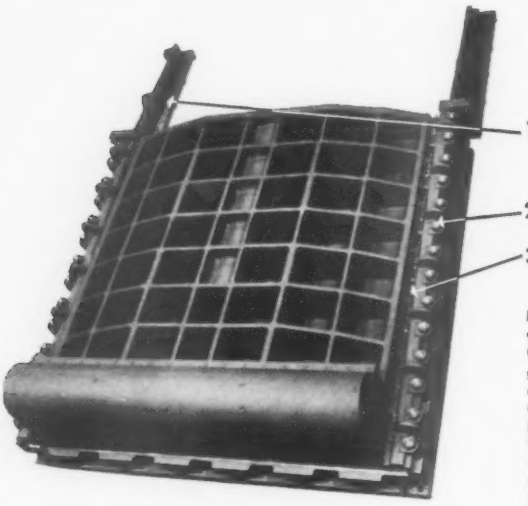

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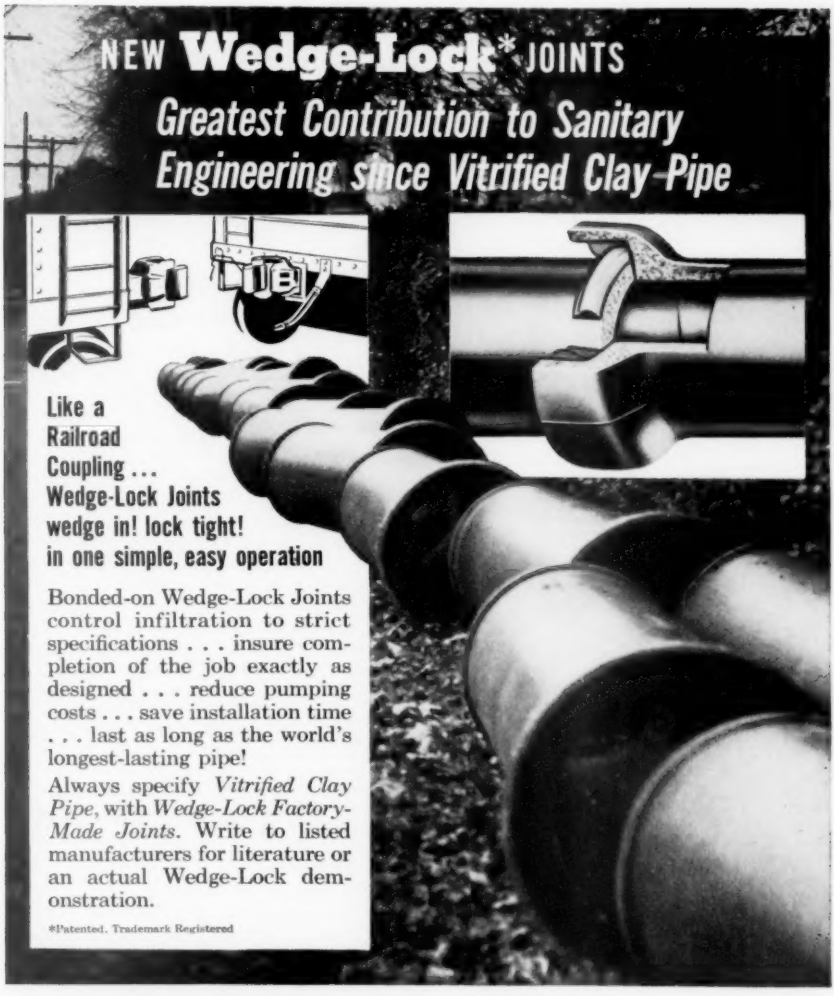
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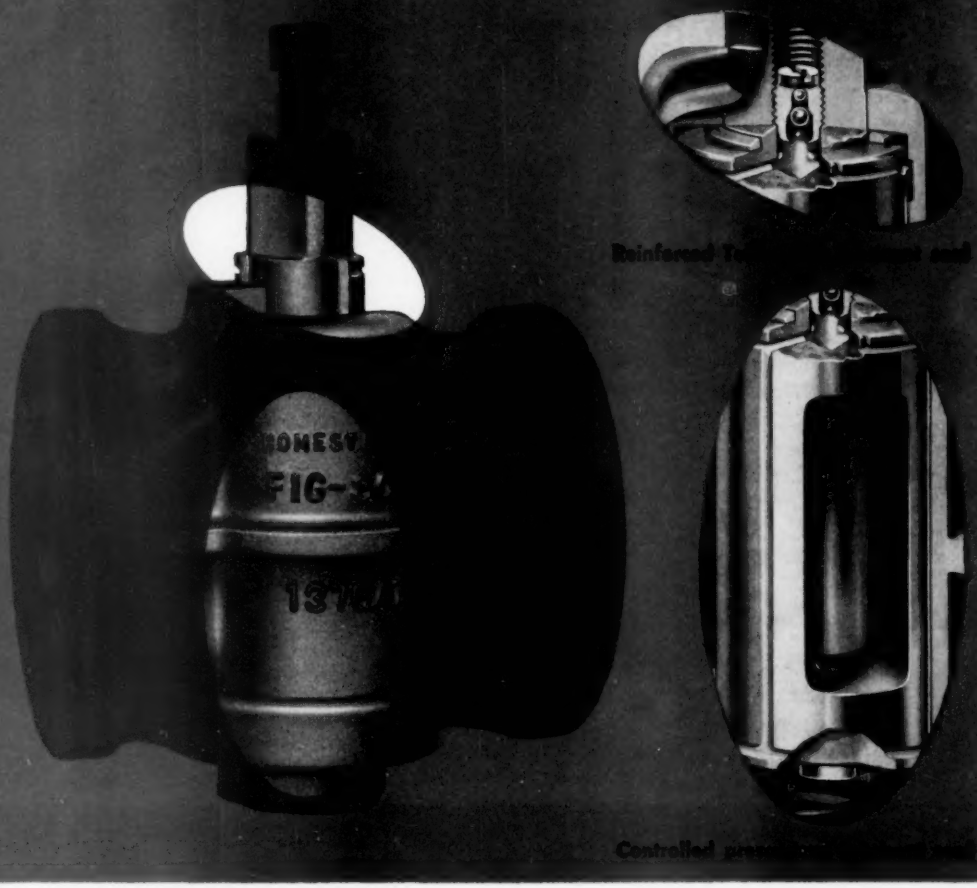

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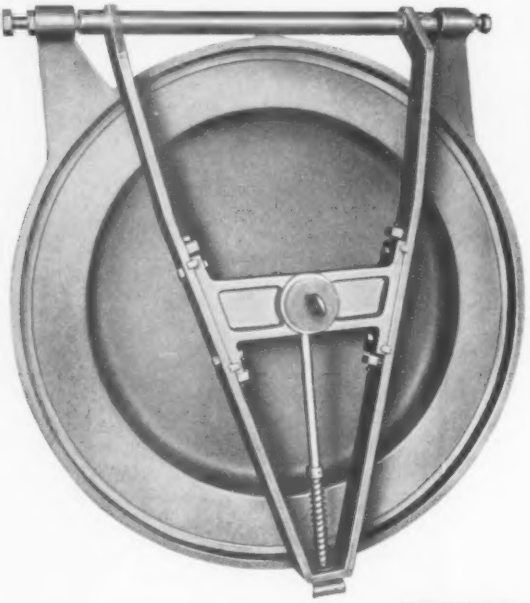

This type of gate, manufactured exclusively by Armco, is made of cast steel with stainless steel and bronze fittings to insure free operation at all times.

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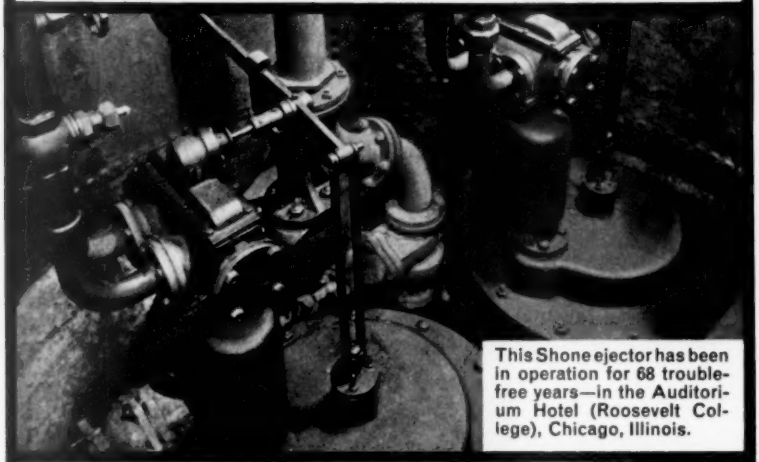

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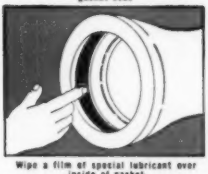
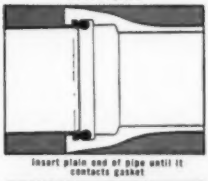
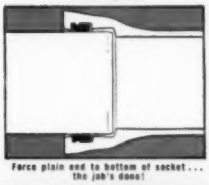
Insert gasket with groove over bead in gasket seat



Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket... the job's done!

12" Tyton Joint pipe for water line in Florida

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AN ORIGINAL WALKER PROCESS DEVELOPMENT

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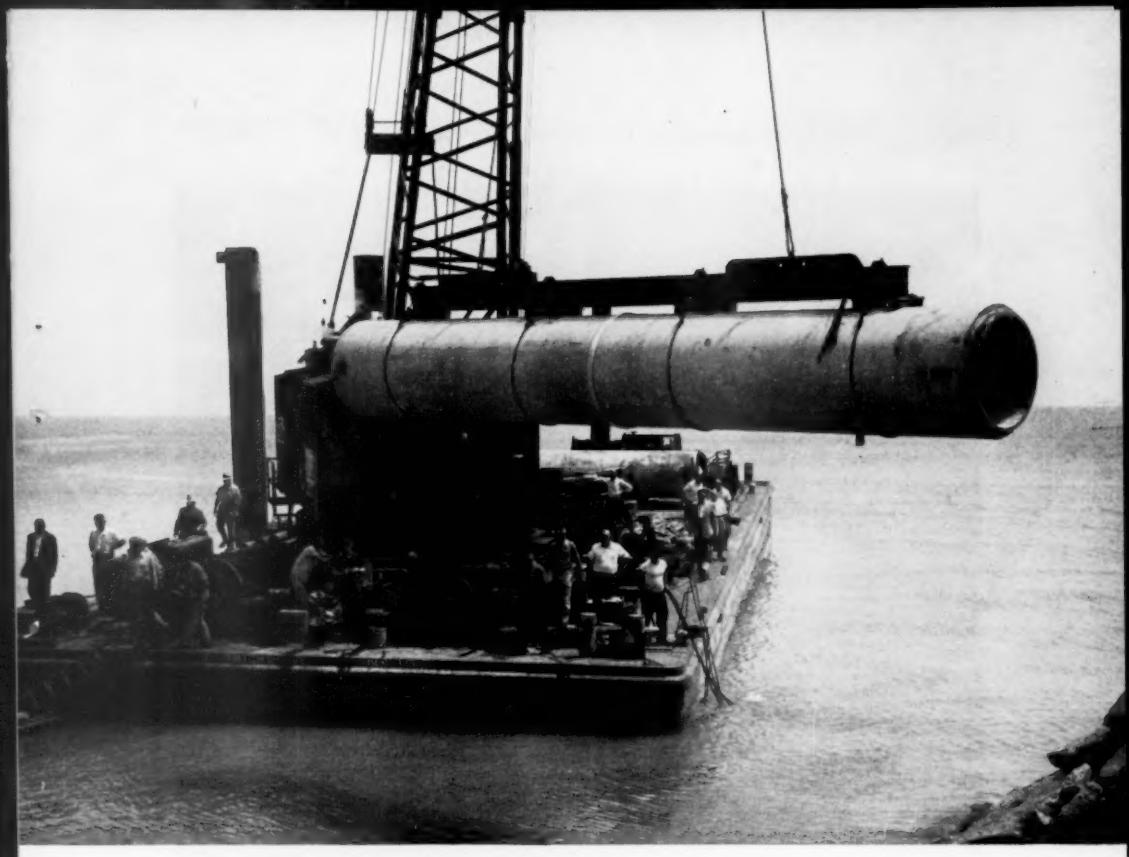

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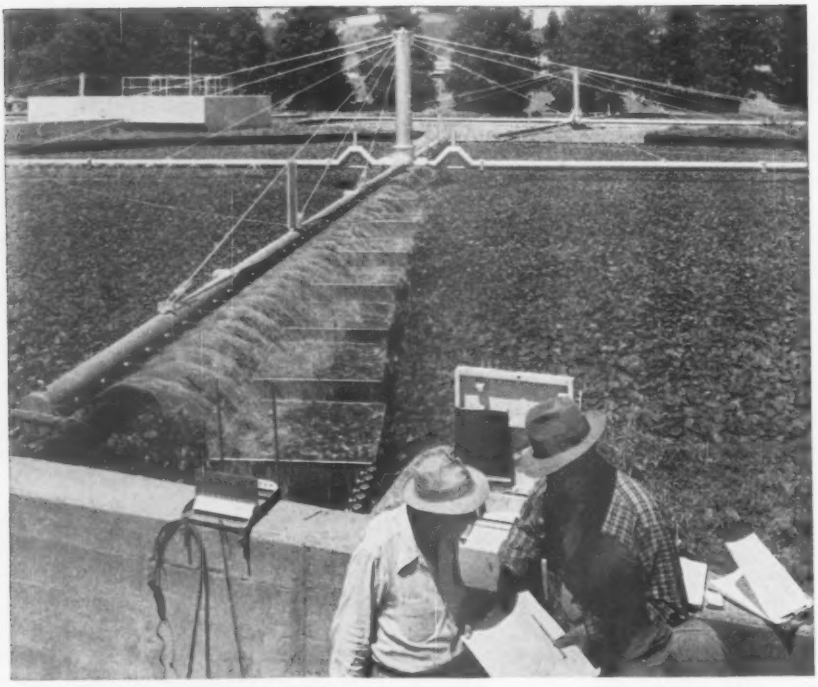
WATER FOR GENERATIONS TO COME



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These P.F.T. Distributors, with proven uniformity of distribution, are the heart of Greenville's expanded new treatment plant.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 30 **June 1958** **Number 6**

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Ralph E. Fuhrman, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.
Robert A. Canham, *Associate Editor* Dr. F. W. Mohlman, *Advisory Editor*
Mrs. Elizabeth Quick, *Production Manager*

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1957 Literature Review

A REVIEW OF THE LITERATURE OF 1957 ON SEWAGE, WASTE TREATMENT, AND WATER POLLUTION

By H. Heukelekian, *Chairman*, R. Manganelli, *Vice-Chairman*, H. Amberg, E. J. Berg, R. A. Canham, C. H. Connell, W. E. Dobbins, G. P. Edwards, M. B. Ettinger, D. G. Foulke, T. deS. Furman, I. Gellman, A. E. Griffin, H. G. Harding, R. D. Hoak, W. M. Ingram, P. W. Kabler, M. Katz, F. W. Kittrell, L. J. McCabe, P. H. McGauhey, W. A. Moore, P. K. Mueller, R. Porges, E. R. Roth, R. C. Specht, A. J. Steffen, C. Straub, C. M. Tarzwell, G. H. Teletzke, W. W. Towne, H. A. Trebler, E. C. Tsivoglou, and R. L. Woodward.

Committee on Research, Federation of Sewage and Industrial Wastes Associations

This second of three sections of the review covers industrial wastes, including radioactivity. The first section, dealing with analytical methods and sewage, was published in the May 1958 issue of This Journal. The third section, on water pollution, will be published in the July 1958 issue of This Journal.

Industrial Wastes

FOOD PROCESSING WASTES

Canning

A list of 102 references with abstracts related to canning waste disposal has been compiled by Green (93). These references exclude canning problems not associated with the Canadian latitudes. While the coverage is not complete, a representative group of canning waste references (primarily from 1948 to 1955) is included.

In summarizing the problems of waste disposal in the canning industry Canham (38) (40) points out that to produce 700 million cases of canned food annually the industry uses 36 bil gal of water. For this production it is estimated that the annual outlay for treatment is nearly 5 million dollars, or about two-thirds of a cent per case. Further, a prediction is made for the cost of treatment to reach nearly 5 cents per case in the next few years. The urgency for the cooperative approach to the solutions of the waste problems is emphasized.

Combined treatment with domestic sewage has received further attention. In a discussion of the current problems of canning waste in California, O'Connell (173) recommends that if combined waste flow from canning

and domestic sources has a BOD greater than 450 to 600 ppm, separate treatment should be provided. He predicts that combined treatment will be simplified with continued population growth. A considerable portion of the California problem is attributed to the solids, both settleable and suspended. A recommendation for special consideration of the disposal of the garbage phase of canning waste is made for the future.

Brown (27), Clinton (44), and Belick (18) also describe combined treatment.

Analytical problems have been considered by McNary *et al.* (157) and Skalski (202). McNary *et al.* discuss comparisons of the various methods of COD determinations as applied to citrus waste. The development of a colorimetric COD method is described for citrus wastes and recommended for use when some of the accuracy of the Moore procedure can be sacrificed for greater speed and less manipulation.

Skalski discusses the relative merits of BOD and permanganate oxygen demand ($KMnO_4$) for use with the analyses of organic constituents of food wastes.

For those canning regions that have available areas within pumping distance, the land methods of liquid waste disposal continue to predominate, since the relative economy and reduced problems of stream pollution and odor control are attractive factors. Canham (39) discusses in detail the spray irrigation method and offers a number of problems for future consideration, including cover crops, fertilizing potential, pH limits, solids inclusion, effects on forests, and soil conditioning.

Seabrook (194) reviews a well-known and successful spray irrigation system wherein the peculiarities of soil and cover crop made it possible to apply unusually large amounts of waste. He further discusses effects on the forest and ground water.

Jackson (112) and Toth (216) describe details of individual spray irrigation installations. Toth reports for a heavy clay soil application rates of 0.25 in. per hour, with a total of 1 in. per lateral setting.

Lefebvre and Dickinson (141) review current practices and possibilities of handling canning waste in Belgium and England. Spray irrigation is considered desirable, while complete biological treatment has not been economically accepted.

At a canning plant where spray irrigation is used, Lunsford (148) approaches the waste disposal problem from the point of view of the stream effect. In the cited instance a seasonal pea canner used spray irrigation to dispose of concentrated wastes and retained the use of the small community treatment plant for the balance. One year's results formed the basis for the conclusion that this was a satisfactory solution since effects on the stream did not account for any complaints.

A particularly concentrated and troublesome waste associated with pea-canning operations is discussed and the agricultural value of land disposal considered, as Forbes (80) describes the collection of pea vine ensilage and its distribution on fallow land. Ensilage juice flow varied from 500 to 2,000 gpd per viner unit. Fertilizer value was computed to be $8 per 1,000 gallons, derived from 4,800 ppm organic nitrogen, 3,500 ppm potassium, and 1,650 ppm phosphate.

Citrus waste problems continue to receive the attention of Lackey *et al.* (134). In a discussion of the present status of knowledge and treatment accomplishment the results of aeration treatment are highlighted. It has been demonstrated that in citrus wastes containing as much as 6,000 ppm BOD there can be 90 to 95 per cent BOD removal if:

1. pH is controlled between 7.0 and 8.0.

2. There is an adequate supply of nitrogen and phosphorus.

3. Aeration is provided as long as 6 hr to remove toxic oil.

4. There is a high recirculation ratio for sludge return.

Additional aeration as long as 16 hr will permit biological attack of pectin.

Waste problems in the fish processing industry are increasing in importance. Paessler and Davis (176) report on the status of waste control in a number of fish oil and meal processing plants. Concentrated low volume waste strengths to 13,000,000 ppm BOD are present, and it is not unusual to find stickwater with 100,000 ppm BOD. Installation of evaporators for stickwater has reduced the load as much as 93 per cent, although the remaining 7 per cent still posed a pollution problem. Collection of all sources of waste for evaporation has been the basis for improvement.

Schulz (191) describes chemical precipitation of the fat-protein emulsion in fish processing wastes, using Al_2O_3, lime, and $FeCl_3$.

Sugar

In the sugar industry there are reports from other countries as well as the United States showing a variety of approaches to the waste problem.

Combined research efforts by eight cane sugar mills to improve waste control are reported by Wheeler and Keller (228). In-plant changes to reduce losses are emphasized. A figure of $100 to $2,500 per day product loss from evaporator entrainment into barometic condenser cooling water is cited as one example of the economic significance.

Le Clerc *et al.* (140) give descriptions, including design data, of the settling basins and treatment plants of 5 sugar refineries in Belgium.

Agricultural utilization of sugar processing solids is reported in Russia (177), while results of biological treatment of beet-sugar waste are discussed in Czechoslovakia (212).

Other foreign work is reported (105) (153) wherein raw product handling improvements are suggested and recirculation of process water is recommended.

Edeline and Le Clere (67) discuss lagoon treatment of sugar wastes. Counter-current cycling through a series of settling basins is utilized and it is said that a large basin can be used if predecantation is practiced. It is further stated that closed circuit operation is possible if accompanied by chlorination.

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Kazvaki, I. E., "On the Pollution of River and Drinking Water by the Wastes of Starch Plant. Studies on the Pollution of the River Water." *Acta Med. Shikoku* (Japan), **8**, 5, 6 (1956); *Pub. Health Eng. Abs.*, **37**, 8, 24 (1957).

Reploh, H., "Water and Sewage Problems in the Starch Industry." *Stärke*, **8**, 195 (1956).

Siebert, K., "Foaming-off and Defoaming of Potato Juice." *Ernährungsforschung*, **2**, 127 (1957).

DAIRY WASTES

Practically all authors stress the importance of waste saving, but there are no particularly new waste-saving techniques or new methods of waste utilization.

Fleer and Baltjes (79) report from Holland of experiments on how much milk can be saved when dumping milk, at various temperatures, from cans with or without a small pre-rinse that is collected together with the drip milk. About 80 per cent of the milk remaining in a can after dumping can be saved. In general, the results confirm experience in this country with pre-rinses on can washers (reported in earlier years). It is interesting to note how much more milk is retained in the cans at the very low temperatures required for delivery of high-quality milk than at the somewhat higher

temperatures sometimes encountered in practical operations (159 ml per can at 5–10°C; 138 ml per can at 10–15°C; and 84 ml per can at 15–20°C). Consequently, the more satisfactory the temperature of the milk received, the higher the losses and the more important it becomes to use a pre-rinse, preferably warm.

The Subcommittee on Dairy Waste of the Dairy Industry Committee (54) (55) has continued its efforts in encouraging waste saving and waste research already reported in previous years. Steffen (206) describes briefly the various research projects now under way in various institutions, mostly under contract with the United States Department of Agriculture. A preliminary report on two of these projects is mentioned below (25) (163).

Investigators agree that irrigation is the simplest and most economical method for dairy waste disposal wherever sufficient land with suitable topography and soil available. Schraufnagel (190) reports on 20 ridge-and-furrow dairy-waste irrigation installations in Wisconsin and Minnesota. Conditions vary greatly from plant to plant and problems are obviously encountered. In general, results appear to be satisfactory and the installation and operating costs are relatively low.

Breska *et al.* (25) make a preliminary report on an extensive investigation of six selected spray-irrigation installations for dairy wastes in Wisconsin. The effects of soil, topography, climate, and loading are all being studied. Kuhlmann (131) reports on spray irrigation with dairy waste. He and others, in Germany, favor the use of a very small (about 400 gal) closed aluminum-holding tank located higher than the pumps. The entire installation is placed in the basement or in a dry pit outside the dairy. The reason for the small tank is to maintain the waste as fresh as possible. Others have favored a storage-tank capacity of about one-third of a day's flow with an arrangement for keeping the sides of the tank washed down, either by recirculating part of the waste or by the use of discharged cooling water.

Schulz-Falkenhain (192) discusses the use of algae ponds (oxidation ponds or lagoons) used for domestic wastes in the United States and points out that one plant in the Rhineland district of Germany has been using this type of treatment successfully for dairy wastes for a number of years. Another installation is being used successfully for combined municipal and dairy wastes. Unfortunately, no data are given on loadings or results.

While it is clearly indicated that, wherever possible, irrigation should be used in preference to more complicated and expensive treatment processes for dairy waste disposal, there are still many locations where other more compact treatment units are needed so that the various modifications of the activated sludge process are still very much in demand. It is becoming clear that activated sludge with proper modification is not difficult to control and is able to handle surprisingly large overloads.

Siebert (198) discusses the modified activated sludge plants used for dairy waste treatment in Pennsylvania and comes to the important conclusion that, in spite of the many statements to the contrary in the literature in earlier years, it is not economical or practical for a number of reasons to operate modified activated sludge plants and rely on endogenous oxidation of the sludge in the aeration tank for sludge volume control. Some means for disposal of excess sludge must be provided wherever a reasonably clear effluent is required.

Fritsch (85) gives a preliminary report on laboratory tests in Germany with activated sludge treatment of synthetic dairy waste with and without the addition of 20 ppm Fe (added as ferrous sulfate). The greatest benefit of the iron appears to be in the im-

proved digestibility of the excess sludge. The greatest advantage of the activated sludge treatment over trickling filter treatment is in the saving of space. The final report will presumably give more complete data.

James (113) gives information about the selection of the proper pumps for the operation of aeration ejectors in dairy waste disposal plants.

Morgan (163) reports on the costs of treatment of milk waste by single-stage and two-stage high-rate trickling filters based on the study of two installations in Wisconsin.

In Germany there is more concern about the possibility of spreading human or cattle diseases through dairy wastes than there is in this country. Treiber *et al.* (217) describe a thermochemical method for the treatment of dairy waste. This consists of taking the waste as fresh as possible and heating it under pressure to 150°C with 80 per cent heat regeneration, followed by tubular holding for 10 sec. This produces sterility and simultaneously precipitates albumin and globulin. Lactose is largely decomposed and caramelized by the high heat. Casein is precipitated chemically with calcium chloride and sodium hydroxide in two conical-shaped settling tanks (about 2,600 gal each) equipped with agitators and chemical feeders. The sludge appears to be valueless because of the high mineral content and no particular method of disposal is suggested. The final BOD is 129 ppm which can be further lowered by mixing with cooling water.

Schulz-Falkenhain (193) discusses disinfection of waste waters by various means and comes to the conclusion that any sterilization method for dairy waste, including the method described above, is prohibitive in cost.

In regard to anaerobic fermentation of dairy waste and dairy by-products, Steffen (206) mentions studies by the Public Health Service. In this work it appears that there are the same difficulties as found by other investigators of getting away from acid fermentation and over into the more desirable and more complete methane fermentation.

Marek and Svoboda (154) have published a report in German, and Svoboda (210) a later report in Czech summarizing the dairy waste activities in Czechoslovakia. They found that the two-stage fermentation treatment followed by filtration over peet recommended by Pien in France (reviewed in earlier years) is best suited for Czech conditions. From the earlier description of the process by Pien and the present description one is led to the conclusion that both fermentation stages are essentially anaerobic, although the first stage may be less so than the second stage.

Svoboda and Salplachta (211) report that *Oospora lactis* (*Geotrichum candidum*) will not destroy lactose directly, but will destroy lactic acid after this has been produced by other organisms.

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PACKINGHOUSE WASTES

Major interest is still centered in anaerobic digestion. Pietraszek (179) presented an account of the operation of the new plant at Albert Lea, Minnesota, including operating data showing 95.9 per cent BOD removal at a digester loading of 0.1625 lb per cfd. Detention periods in the digester averaged 14.32 hr based on raw feed and 3.55 hr based on total flow including return sludge. The plant design is described by Duvall *et al.* (63). Lloyd and Ware (144) reported on pilot studies with slaughterhouse wastes averaging 2,300 ppm BOD in continuous flow anaerobic digestion at 92°F, and showed 93 per cent BOD removal in 16.5 hr at digester loading of 0.136 lb BOD per cfd. Slow stirring of the digester contents was necessary and speed of stirring was critical, since both insufficient and excessive stirring produced poor results. Under optimum conditions a light, easily settled sludge was produced, and the digester effluent was treatable on trickling filters at loadings of 70 gpd per cu yd with the final effluent averaging 8 ppm BOD.

Attempts at digesting blood with domestic sewage sludge at 9 parts blood to 91 parts sewage sludge (volumetric) failed (200). Carbon dioxide in the gas increased to 65 per cent; the BOD of the supernatant increased to 11,000 ppm; and total solids in the supernatant increased to 2.24 per cent. Excessive foam and scum and objectionable odors were also reported.

Operation of a pilot-scale trickling filter following a flotation unit was reported by Hirlinger and Gross (107). Customary additions of alum to improve flotation did not appear to impair efficiency of the trickling filter. A BOD loading of 3.53 lb per cu yd at 20.35 mgd/acre produced BOD removals of 50 per cent. A BOD loading of 2.06 lb during non-kill hours resulted in removals of 61.2 per cent.

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FERMENTATION, CHEMICAL, AND PHARMACEUTICAL WASTES

The use of incineration as a means of disposing of concentrated or potentially toxic organic wastes was discussed by several authors. Gurnham (97) described incineration practices used at a large pharmaceutical plant for disposal of non-recoverable waste solvents. These are presettled to avoid burner nozzle clogging, pumped through a 100-mesh screen, and introduced to the furnace through a series of nozzles at 15 to 18 psi. From 1,600 to 1,800 gal are disposed of in each 16-hr operating period. No waste heat recovery is practiced.

Garrett (87) provided details on the incineration of aqueous waste from acrylonitrile and vinyl chloride production. Furnace temperatures range from 1,050°F at the breech to 1,500°F in the combustion zone. The feed organic content ran as high as 3.5 per cent, including several soot slurry streams. The furnace disposes of 30,000 gpd with supplemental heat received from combustion of from 300,000 to 500,000 cu ft natural gas each day.

Rocheleau (185) discussed several incinerator types used at various Du Pont installations. Some are designed for both liquid and solid wastes while others, including a horizontal cylindrical refractory-lined unit, are used only for liquid wastes. The use of water scrubbers is mentioned for removal of HCl from exhaust gases from incineration of waste-chlorinated solvents.

Eustace and McVeigh (71) reported on a pilot plant study of sedimentation treatment of combined effluent from a photographic materials and organic chemicals plant. Mechanical flocculation prior to sedimentation produced satisfactory results. Lime addition to the resultant sludge to maintain pH 9 and an alkalinity, as $Ca(OH)_2$, of over 1,000 ppm insured satisfactory sludge dewatering on a vacuum filter. Cushman and Hayes (53) described results of a pilot plant study of multistage trickling filter treatment of various blends of sanitary sewage, chemical process wastes, and fermentation spent broths. First stage BOD removals exceeded 80 per cent at loadings of from 500 to 3,500 lb per day/acre-ft. The secondary filter generally produced removals exceeding 60 per cent at loadings of 50 to 300 lb per day/acre-ft. Van Blarigan and Lamb (223) discussed the application of statistical techniques to the design and interpretation of pilot plant trickling filter treatment studies for effluent from a large organic intermediaries and dyestuffs plant. Temperature was found to influence markedly the degree of BOD removal, which varied from 85 per cent at 80°F to 60 per cent at 40°F, when the filter was loaded with 1,000 lb per day/acre-ft at a 3:1 recirculation ratio.

A study of solvent removal from aqueous wastes by aeration was reported by Eckenfelder *et al.* (66). Ethanol, acetone, and methyl-ethyl-ketone, alone or in admixture at 1,000 ppm concentration, were studied. An exponential increase in solvent removal rates was noted with linear temperature rise. Residual solvent concentrations were determined by the oxygen-consumed procedure employing a silver catalyst.

Wright (233) described waste treatment facilities at a large petrochemicals plant, which included grit removal and screening, clarification, and chlorination prior to discharge. Stronger wastes are treated in a series of oxidation basins which are loaded at a rate

of 100 lb per day/acre and which produce a 95 per cent BOD reduction. Federgreen and Weinbergern (77) reported the development of a new process for treatment of spent acid-catalyst wastes from production of methylstyrene from toluene acid acetylene. Recovered mercuric catalyst is re-used, as is toluene recovered from the waste. The salvaged sulfuric acid is used for fertilizer production. The recovery process involves steam stripping as a basic separation step.

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COAL WASTES

The problem of enonomical recovery of coal from washery effluents received considerable attention in 1957. Fouquet (82) noted that slimes from coal washeries comprise coal, schist, quartz, sandstone, pyrite, and clay, with particle sizes ranging from 0.9 to 15 mm. The highest ash contents occur in the finest fractions, which are mostly clay. The clay can be peptized with a few ppm of rhodamine and readily separated in a settling cell. After removal of the clay the rate of horizontal circulation can be adjusted to permit separation of the other components. El'yashevich (69) reported the following data on cleaning Donetz fines by flotation. A coal treated with 0.5 per cent sodium chloride solution and 3.3 lb sulfonated kerosine per ton gave 88.32 per cent concentrate with 8.30 per cent ash, and 11.68 per cent of tailings with 71.38 per cent ash. Another coal treated with 2.0 per cent sodium sulfate solution and 0.88 lb sulfonated kerosine per ton yielded 87.50 per cent concentrate with 7.28 per cent ash, and 12.50 per cent tailings with 68.40 per cent ash. The author noted that increasing the amount of electrolyte reduces the kerosine requirement. Other advantages of electrolyte additions are removal of fusain and high-sulfur components; reduction of coal loss in tailings; suppression of moisture in the product; and acceleration of clarification of flotation water. Koibash and Sokolov (127) found that a liquid by-product from a soda-plant waste water consisting chiefly of salts of sodium, calcium, and magnesium, when added with sulfided kerosine to a coal flotation cell, increased the capacity of the equipment 30 per cent and the yield 2 per cent. The addition improved filtration and gave a concentrate with 2 per cent less moisture. Klassen and Pikkat-Ordynskii (125) observed that, in heavy-mineral flotation, other things being equal, the greater the amount and speed of drainage between individual bubbles, the more effective is the treatment. They used a water-spray attachment that delivered water at the rate of 1.6 gpm, 10 in. above the foam. Typical results with sulfonated kerosine or turpentine were: for a raw feed of 17.2 per cent ash the yield without spraying was 41.5 per cent concentrate with 7.2 per cent ash, and 58.5 per cent tailings with 24.4 per cent ash; with spraying the yield became 53.6 per cent concentrate with 6.6 per cent ash, and 46.4 per cent tailings with 29.8 per cent ash. They pointed out that sprays that break the foam must be avoided.

Drexler and Franke (61) stated that long-chain heteropolar compounds, e.g., polyacrylic acids of about 50,000 mol wt, are excellent clarifying agents for washery waters containing electrolytes. As little as 0.1 ppm will reduce the coal content of an effluent to 1 ppm from 50 ppm. Filtration of the sediment is easier because sliminess is reduced. The same polymers can be

used to separate clay from water. Coxon (50) presented arguments in favor of a continuous operation in which fluidized coal would be fed to a reactor vessel to produce liquid products that could be distilled or cracked, as in an oil refinery.

The most important factor for determination of the quality of mine water is the total acidity or alkalinity measured by titration to a phenolphthalein end point in hot solution. Braley (24) emphasized that pH is only a qualitative indication of acidity or alkalinity in highly buffered solutions; it is variable, depending on the state of oxidation of the iron. Free acid is not only variable but has little meaning in solutions containing only strong acids and their salts. Use of a common method for evaluating mine water would eliminate misunderstanding of the effects and control of mine acid.

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COKE OVEN WASTES

Countercurrent extraction of phenol from waste water with an immiscible solvent of lower specific gravity, e.g., benzene or toluene, was reported by Auvil and Schmidt (17). Solvent from first extractor is treated with aqueous caustic soda in a second extractor for recovery of sodium phenolate. The washed solvent is recycled to the first extractor. Waste containing 1,070 ppm phenol was reduced to 66 ppm with 0.635 lb caustic per lb phenol. Phenol was reduced to 8 ppm with a 1:1 caustic-phenol ratio. Tomikura (215) patented a process for recovery of phenols. A gas liquor (200 l) containing 2.43 g phenols per liter was extracted countercurrently with a mixture of 180 l benzene and 20 l xylidene; 82 per cent of the phenols was recovered. Manka (150) developed a process for extracting phenols from water with an equal volume of a mixture of an aromatic hydrocarbon and 2-methyl-5-ethylpyridine. Treatment of water containing 128 to 278 ppm of phenols with an equal volume of toluene containing 1 per cent of the methylethylpyridine by volume, removed all but 1.3 ppm of the phenols. Temperatures of 25 to 65°C are satisfactory; the pH should be in the range of 6.5 to 9.5.

Peremyshlin (178) found that butyl acetate extraction of water containing 4.61 g phenols, 605 mg hydrogen sulfide, and 4.66 g ammonia per liter gave a product containing 0.73 g, 3.66 mg, and 3.68 g per liter, respectively. Phenol could be further reduced by normal biological processes after dilution, e.g., 107 mg per liter reduced to 1.07. Deljagin (58) reported that a coke plant waste containing 12 g phenols per liter, after extraction with butyl acetate and biological treatment of the raffinate plus domestic sewage, yielded an effluent with 0.1 ppm phenol. The mixed waste was aerated for 8 hr. This is a commercial installation in Russia. Reed *et al.* (183) found that biological slimes grown on drums remove phenol more slowly than in aeration tanks, but they are tolerant of much higher concentrations. Optimum loading was in the range of 1,000 to 1,500 ppm. Chromium did not inhibit the process. Addition of nutrients in the form of a commercial fertilizer (Vigoro) was necessary.

The Collin liquid purification plant at Corby, England, was described by

Doerges (60). Recirculated ammonia liquor, which absorbs hydrogen sulfide selectively with a minimum of carbon dioxide, is used to scrub the coke oven gas. Hydrogen sulfide is liberated by heating the scrubbing liquor and is converted directly to 60°Bé sulfuric acid by wet catalysis. The acid has a low content of nitric oxide which is further reduced to less than 0.01 per cent by adding urea. Operating data are given in the paper. McNeil *et al.* (158) patented a process for making water-white naphthenic hydrocarbons by hydrogenation of coal tar. An acid- and caustic-washed coal-tar fraction containing 0.95 per cent sulfur is fed over a cobalt-molybdate catalyst with hydrogen at 410°C and 32 atmospheres. The tar is fed at 1 liter per liter of catalyst space per hour, and hydrogen at 500 liters per hour. The product, containing 0.01 per cent sulfur, is washed to remove hydrogen sulfide, and passed over 65 per cent nickel on kieselguhr at 300°C and 32 atmospheres, at one liter per hour and hydrogen at 4,000 liters per hour. The product is useful for motor, jet, or diesel fuel, solvent, plasticizer, or heat-exchange fluid.

Liquor from the gas industry is an aqueous solution of many substances and contains 1 to 4 per cent nitrogen. Webber (227) treated grass, kale, and a cereal crop with this liquor (1.77 per cent N) at a 300 and a 600 gal per acre rate. On grass the liquor was inferior to ammonium sulfate as a fertilizer, and it often caused scorching. On cereals it equalled 0.66 to 0.75 the value of ammonium sulfate. On kale both fertilizers were equally effective when comparable amounts of nitrogen were used.

Zhukov *et al.* (236) reported that activated sludge is better than pure strains of especially active bacteria for purifying phenolic waste waters. The difficulty of keeping the strains pure in industrial use is advanced as the reason for this. Viehl (224) described the problem arising from discharge of phenolic wastes to German rivers, with special reference to the Pleisse which is heavily polluted with wastes from the manufacture of benzene from brown coal. The effect of phenols on fish and other organisms is given, together with brief accounts of methods for extraction or destruction of phenols in waste waters. Hoak (108) discussed the complex factors that must be considered in evaluating the causes of tastes and odors in drinking water. Threshold odor determinations on pure phenolic compounds disclosed an enormous difference in the thresholds of different compounds and among their isomers. The author advanced the hypothesis that most tastes and odors come from decaying vegetation. A laboratory fermentation of oak leaves showed that, over a period of 75 days, the substrate contained a fairly constant average concentration of AAP phenol of 264 ppb. Data from a two-year survey of the Monongehela and Ohio rivers showed that, while the discharge of phenolics from coke plants was about 4,000 lb per day, phenol loads ranged from 10,000 to 25,000 lb per day for considerable periods of time, especially following heavy runoffs from rainfall. Laboratory study of the dissimilation of phenolic material showed that the rate is a function of molecular complexity. Pure phenol was destroyed in hours, as compared with days for the phenolics from natural vegetation and domestic sewage.

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PETROLEUM PROCESSING WASTES

A combination chemical flocculation-biological oxidation unit is described briefly (13). Emulsions are broken with a ferric salt-lime-air treatment and BOD is removed in an activated sludge unit.

Biological oxidation of various organic compounds is presented by Hatfield (103). BOD reductions of alcohols, aldehydes, acetone, acetic acid, and copper formate were studied. Primary and secondary alcohols were readily oxidized (the majority of BOD reduction occurring in four hours) but tertiary alcohols and glycols were found resistant to biological oxidation. Different rates of oxidation were observed according to the degree of acclimatization of the sludge. COD analyses are pointed out as being an important method of following biological oxidation rates. Cooke described comparative biological oxidations of glucose and hydrocarbon (motor oil) in studying the nutritional requirements of common sewage fungi (48). Glucose or hydrocarbon (0.5 g) in 50 ml solution was inoculated with 1 ml of spore or cell suspension, shaken for 120 hr, filtered, oven-dried, and weighed. Ratios of the dry weights of replicates where growths in oil exceeded growth in glucose are as follows:

Fungi	Ratio Oil to Glucose
Fusarium aquaeductuum	2.49
Geotrichum candidum	6.18
Penicillium lilacinum	7.58
Margarinomyces heteromorphum	3.96

Cahnmann and Kuratsune (36) presented the results of determining the amount of polycyclic aromatic hydrocarbons in oysters growing in moderately oil-polluted waters. Aside from the analytical techniques, the data are stated to be significant in that a pick-up of hydrocarbons was demonstrated. About 1 mg of polycyclic aromatic hydrocarbons was detected per kg of shucked oysters.

Interesting observations and conclusions of a 15-month survey of a stream containing refinery wastes were presented by Ludzack *et al.* (146). A 30-mile section of the Ottawa River, Ohio, below the refinery discharge, was studied. Municipal activated sludge effluent (12 to 19 cfs), petrochemical plant wastes (2 cfs), and refinery wastes (3 to 6 cfs) combine at essentially the same point in a total river flow of 19 to 30 cfs. Mineral oil content of the river water decreased rapidly to approximately upstream values (80 per cent decrease in 1 mile during summer and 40 per cent decrease in winter with a total elapsed time of about 4 hr). Separated mineral oil appeared as a surface film, bottom sludge deposits on banks, and probably some biological degradation deposits. Parallel laboratory studies indicated 50 to 80 per cent aerobic biological decomposition per week at summer temperatures. It was concluded that the primary problems were related to the formation of oily bottom sludges. Also, the general observation is made that little anaerobic decomposition takes place in bottom sludges. Sludges are postulated as being formed through physical entrapment of emulsified oil globules in biological matter, weighting with silt, and settling.

Bio-assay procedures and results on a number of pure chemicals encountered in refinery effluents were described by Wallen *et al.* (225). Toxicity of 86 pure chemicals plus turbid pond waters were tested as a potential approach to toxicity of total wastes in an area where high turbidities are encountered a high percentage of the time. Other chemicals not tested but thought important are listed. Chemicals which gave a $TL_{m\ 48}$ of less than 50 ppm are as follows:

Chemical	TL_{m-s} (ppm)
Ammonium hydroxide	37
Cresol	24
Furfural	24
Potassium cyanide	1.6
Sodium nitrite	7.5

Turbidities for the toxicity tests ranged from 121 to 3,000 ppm. Tests to determine the effect of turbidity alone indicated fish survival in turbidities greater than the recorded maximum for the state (18,000 ppm).

A German process for recovery of phenolics was given by Benman (20). Sodium carbonate is mixed with the feed to a steam stripping tower operated at 5 to 10 atmospheres pressure. The mixture is converted to carbon dioxide, sodium phenate, and water. The bottom phenate water is contacted with the carbon dioxide to free the phenols and further distilled to recover the phenols and regenerated sodium carbonate solution. The method is claimed to be economical and continuous, requiring only steam as a reagent and eliminating any further waste products. A solvent extraction process for removing phenolics was presented by Heller (104). A Shell Development Company rotating disk contacter is used in conjunction with a solvent to reduce the phenol content of a waste stream from 5,000 to 9 ppm. Investment is $125,000 for a 12,000 gpd unit. Solvent extract is re-extracted with caustic and recycled, with phenolics being recovered from the caustic when it is 90 to 95 per cent saturated.

Davies (57) illustrated with examples the "waste prevention" approach which has universal application. Through concentrated effort the use of various toxic chemicals and emulsifying agents was eliminated or minimized by extention of solution life, effective drainage, etc. Non-ionic organic coagulants aids are used in conjunction with normal coagulants in chemical coagulation waste treatment.

Progress and details of the international agreement on sea water pollution by hydrocarbons was given (15). The agreement forbids the discharge of materials containing 100 ppm or more of hydrocarbons within specified coastal zones.

Waste treatment for shale oil plant wastes in Sweden and at several European refineries are described (70). Shale oil waste waters (1.5 to 2 mgd) are steam stripped, contacted with hot waste shale ash, lime softened, aerated, and settled.

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PICKLING AND ACID WASTES

In a series of five papers, Slade (203) presented a detailed analysis of spent acid reclamation. Using a ternary diagram for the system $FeSO_4$-H_2SO_4-H_2O he traced the results that could be achieved by various treatments of spent pickle liquor, viz., straight cooling, isothermal evaporation, vacuum evaporation, high-temperature evaporation, and addition of strong acid. The author also discussed the design of a pickle liquor evaporator-crystallizer. Roy and Allen (187) patented a process for recovering values from pickle liquor. A kilogram of pickle liquor (15 per cent $FeSO_4$, 2 per cent H_2SO_4) was added to 900 g of 10 per cent hydrated lime slurry and the mixture stirred until precipitation was complete. The mixture was filtered, the coke suspended in 300 g of water plus 110 g of ammonium carbonate, and autoclaved at 70 to 80°C for 2 hr under 2 to 3 atmospheres of carbon dioxide. The product was filtered and the coke washed with water. The yield was 214 g of iron hydroxide plus calcium carbonate and 105 g of ammonium sulfate solution.

Faust and Orford (76) reported that the sludge from lime neutralization of sulfuric acid could be concentrated and its volume controlled by using gypsum powder as initial seed and recycling the slurry until a desired volumetric loading is attained. The volumetric sludge return for optimum control appeared to be a function of acid concentration and type of lime. Nebolsine (167) published an extensive review of wastes treatment at steel mills in which he discussed current practices in pickle liquor disposal. Groen (96) described a sewer failure traced to discharge of pickle liquor. Upon investigation of the subsidence of a section of street paving it was found that a 6-ft storm sewer and sanitary interceptor had been severely damaged, and that there had been extensive damage to the sewer for a mile upstream. Meters for continuously recording pH, flow, and temperature were installed at a point near the suspected source. The pH record showed an erratic pattern that indicated both slug discharges and attempts at partial neutralization. The latter was confirmed by the presence of large amounts of calcium sulfate downstream from the source.

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PLATING AND CYANIDE WASTES

Papers by Watson (226), Gurnham (98), and Milne and Foulke (161) indicate the trend in metal finishing continues to be toward reduction of waste volume and water conservation. Unfortunately, the methods employed are not new. Waste treatment in the metal finishing industry is rather well standardized and, even though the total number of papers published in 1957 (fifty-odd) is about the same as for 1956, very few introduce new data of fundamental nature.

Sheets (197) discussed the toxic effects of salts used for anodizing, plating, and metal finishing upon the biological processes commonly used in the treatment of municipal wastes. The pilot plant used for studying these effects was a 50 gpm unit operable as a trickling filter or an activated sludge plant.

Using the BOD of the blank (synthetic sewage) as 100 per cent, the per cent recoverable BOD for a number of metals at a known concentration was found. Arbitrarily selecting the point at which the curve of the plotted values crossed the 50 per cent recoverable line, the relative effect of various metals was determined. CrO_3 at 4.0 ppm, $CrCl_3$ at 0.23 ppm, $NiSo_4 \cdot 6H_2O$ at 16 ppm, and NaCN at 3.6 ppm, all buffered, reduced the BOD values by 50 per cent.

In other studies, Sheets shows that a shock load of 10 ppm of CrO_3 for 12 hr or less has no detrimental effect upon the activated sludge process. Some studies were made with several metals present and it appeared that Cu-Cr had an antagonistic effect, Cr-Ni a synergistic effect, while Cu-Ni tended to be antagonistic; but these results should be considered preliminary since the variables which will affect the toxicity limit of activated sludge plants were not studied.

Kittrell (124) reviewed the effect of plating wastes on sewage treatment. He noted that hexavalent chromium is about 100 times as toxic as the relatively insoluble trivalent chromium which settles out almost completely in the primary tank and that biological systems can acclimatize to cyanide, from 1 ppm to as much as 200 ppm of cyanide in experimental studies. Twenty-seven references include a number of private communications.

The ingestion of cadmium on animals was reported (149) to result in a build-up in the kidneys and livers of rats at a concentration of 0.5 ppm, while 10 ppm of cadmium in drinking water of dogs over two years has resulted in no abnormal effects. With 8 ppm of chromate in the drinking water of rats, there was no retention, but dogs showed increased accumulation when the chromate in drinking water exceeded 5 ppm.

Chamberlain and Day (42) present the basic data related to the reduction and precipitation steps of the treatment of hexavalent chromium with sulfur dioxide. The effect of pH on the reaction:

$$2\ H_2CrO_4 + 3H_2SO_3 \rightarrow Cr_2(SO_4)_3 + 5H_2O$$

is such that the rate of reaction decreases with increasing pH, being complete in a matter of minutes up to a value of 2.0 and within practical time limits in the pH range of 2.0 to 4.0. The weight ratio of sulfur dioxide to chromium is given as 2.65:1.0 for a chromium concentration of 50 ppm, but it is pointed out that two factors control this ratio, *i.e.*, a variable chromium concentration (lower concentrations of Cr^{+6} require more SO_2) and a more constant dissolved oxygen

concentration (due to loss of SO_2 to dissolved oxygen). With regard to the precipitation of trivalent chromium, the effluent should have a pH of 8.5 to 9.0. Soda ash tends to form more voluminous precipitates than lime or caustic soda and the slight advantage of the latter precipitate volume-wise does not justify its use as a precipitant in view of the lower price of lime.

Johnson (114) described the destruction of cyanide by boiling highly alkaline cyanide-bearing wastes. Laboratory work showed that dropping 1 liter of the cyanide-containing solution, 16.05 oz per gallon of NaCN, into a 6 lb per gallon caustic soda solution held at 260 to 300°F with aeration resulted in reduction of the NaCN concentration to 0.3 oz per gallon if the solution was held at boiling for 28 hr. A comparison of the economics for this method with conventional methods was not given.

A helpful compilation (160) of local authority by-laws concerned with regulation of English metal finishing effluents is mentioned as a reminder that no comparable American study exists.

Gurnham and Foulke (99) published an extensive listing of 1956 papers having to do with plating wastes and a similar 1957 bibliography (100) may be useful to those interested in supplementing this critical review.

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PULP AND PAPER WASTES

Continuing emphasis is being placed upon the reduction of waste discharges by the pulp and paper industry. Research over the past 10 years by industry-sponsored groups and individual mills has provided a continuous flow of ideas which have been adapted to mill-scale application.

Sulfite

The sulfite industry, because of the magnitude of the problem, has remained the primary target for expanded research budgets. Although the emphasis on by-product recovery continues, this approach does not appear to be an over-all solution for the industry because of the limited market for by-products. Fermentations of spent sulfite liquor is receiving continuing interest because of the high BOD reductions attainable by various microbiological methods.

Kretzschmar (128) reports that the most extensively used treatment methods in Germany are alcohol and fodder yeast fermentations. In some instances, the alcohol fermentation is followed by the fodder yeast fermentation to reduce the remaining sugar in the waste. It is estimated that at the present time 27 per cent of waste solids are utilized and by 1960 this will increase to 64 per cent, with further plans for complete utilization of the rest by evaporation-burning. The operation of a large Canadian alcohol plant is described by Kure (133). The plant treats five to six million gallons of spent sulfite liquor per week and produces two and one-half to three million gallons of alcohol per year. The carbon dioxide by-product is used in an adjacent plant for the manufacture of magnesia insulation. Because of the high sugar reductions attained

by the Torula yeast fermentation, this process is of particular interest to the industry. Dyck (64) describes the process of manufacturing, nutrition values, and uses of Torula yeast. The Torula yeast plant of one of the domestic paper mills has sufficient capacity to process all the company's spent sulfite liquor into 5,000 annual tons of high-quality protein product. Müller (165) reports on experimentation using various strains of Clostridium for the fermentation of spent sulfite liquor. Under optimum fermentation conditions, 80 per cent of the sugars and 50 to 80 per cent of the acetic acid present was consumed.

Additional fermentation experiments are described by Gfeller (89). Amberg and Cormack (4) describe an aerobic fermentation process, capable of reducing 80 to 90 per cent of the BOD of spent sulfite liquor. The process, a modification of the activated sludge process, uses a heavy inoculum of 20,000 to 30,000 ppm of suspended solids and is operated at BOD loadings in excess of 2 lb per cfd of aerobic capacity. High operating costs necessitate the recovery of a salable by-product for practical application.

The roadbinder program of one Michigan mill is described by Suess (209). It was found that spent sulfite liquor was a good roadbinder in concentrations of 10 to 15 per cent. The roads may simply be sprayed, but for best results they are scarified, then graded, and finally treated with roadbinder.

Evaporation and burning of spent sulfite liquor where economically possible remains as one of the most promising means of attaining high BOD reductions. Kann (118) presents a review of evaporation and burning of spent sulfite liquor with particular emphasis on liming of evaporator systems. Design and operating details are presented for various proprietary evaporation and combustion systems. Because of the liming and fly-ash problems associated with the evaporation and burning of calcium base liquor more emphasis is being given to the conversion of soluble cooking bases such as sodium, magnesium oxide, and ammonia. The recovery of heat and process chemicals from sodium base sulfite liquor is discussed in detail by Lung-Mestrezat (147).

One the most interesting and revolutionary developments has recently been reported by Gauvin (88). This atomized suspension technique offers a new method of treating waste liquors with or without chemical recovery. It consists of atomizing the liquor in absence of air into the top of a tower, the walls of which are maintained at high temperature, and of passing the resulting suspension of droplets in the water vapor atmosphere as a carrier through successive zones of evaporation, drying, and chemical treatment, as it proceeds down the tower. Separation of solids, uncondensable gases, and steam is effected by simple means. Sorensen and Douty (204) describe the design of a furnace for the burning of spent sulfite liquor which may function either as an auxiliary or main combustion chamber. Kobayashi (126) reports on the heat treatment of causticized spent sulfite liquor. The sugars were decomposed during the treatment and about 60 per cent of the organic substances were precipitated in one hour at 180°C.

Semi-Chemical and Kraft

With present emphasis on increasing yields and utilization of hardwoods, the various semi-chemical processes have been increasing at a rapid rate. There are a number of recovery systems which have been proposed for the recovery of chemicals and several have shown sufficient promise for mill-scale operation. A review of the most important regenerating processes for semi-chemical pulp liquors is presented by Iwanow (111). Campbell and Shick (37) describe the sulfite semi-

chemical liquor recovery system developed by one of the American paper companies. It is based upon the reaction of carbon dioxide in the furnace flue gases with sodium sulfide in the green liquor to form hydrogen sulfide and sodium carbonate. The hydrogen sulfide is returned to and burned in the recovery furnace and the sodium carbonate is used to scrub the furnace flue gases for recovery of sulfur as sulfite. The over-all plant recovery efficiency may attain 80 to 90 per cent of the sodium and 75 to 85 per cent of the sulfur fed to the digesters.

A process for the recovery of soda-base sulfite liquor is described (11). The process converts the sodium sulfide-carbonate smelt produced in the recovery furnace into the usual green liquor through an evaporation crystallization step to salt out pure sodium carbonate. The remaining mother liquor recycles to react with the raw sulfite liquor, producing a liquor which can be handled in kraft type evaporators and smelting furnaces. All the sulfide in the smelt is converted to sulfur dioxide in the furnace without the intermediate formation of hydrogen sulfide.

Lebo and Hassler (139) presented laboratory studies on kraft mill effluents which indicated that BOD reductions in waste effluent by a trickling filter were as satisfactory as those accomplished by activated sludge treatment.

Paper Mill

Continuing emphasis on water reuse in the paper mill and the installation of save-alls has been effective in reducing fiber losses to streams. Martin (155) discusses the principal features in the method of white water recovery which were outlined as the reduction of solids in machine white water with save-alls, use of retention aids where practical, proper handling and routing of white water to obtain maximum utilization in the machine system, operation of a separate titanium dioxide recovery system, and collection and reporting of sewer flow and loss data. After a brief review of the principles of fiber recovery of save-alls, sedimentation equipment, and flotation installations, Link (143) describes recovery measures taken with the white water systems of three paper machines. Savings effected, factors to be considered, and problems encountered are discussed. Friend (84) discusses the reduction of BOD by the chemical precipitation of effluents containing colloidal suspensions of starch. The addition of lime followed by the addition of alum will precipitate the suspensions and subsequent removal of the materials produces BOD reductions of mill effluent.

A fiber recovery system used to reclaim fibers from knotter and flat-screen rejects is described by Lea (138). The system comprises centrifugal cleaners, disintegrators, stationary screens, and a line of vibrating flat screens. Important gains have been the reduction of fiber loss in the pulp-mill effluent and conversion of a large percentage of material (formerly wasted or processed into a low value screenings product) into a high-grade fully bleached pulp.

Lardieri (136) discusses the factors influencing the choice of the activated sludge process for the treatment of paper mill waste waters. Pilot plant studies were conducted using a conventional activated sludge unit and a contact stabilization unit. Flow diagrams are given and treatment methods of seven paper mills were studied. Problems encountered were: cost of nutrient additions, cost of neutralization chemicals, failure to remove color, foaming, and disposal of excess sludge. Betts *et al.* (21) discuss experimentation and surveys to obtain data to determine allowable pollution loads and most economical size of treatment plants. The general bio-oxidation process was found applicable to paper machine waste waters.

A biological treatment unit has been installed in two adjoining mills making straw paper, strawboard, and toweling (16). The new effluent treatment system reduces the BOD and separates fibers which are returned to the mill. The biological treatment involves lagooning the effluent, drawing it into activated sludge tanks, pumping domestic sewage into tanks, and blowing compressed air to promote oxidation.

At a deinking mill, an activated sludge unit has been installed to handle 350 gpm of deinking waste with a maximum of 1,000 ppm BOD (9). This unit is designed for the treatment of high BOD wastes. Cost and size comparison are made between activated sludge units and trickling filters.

TANNERY WASTES

Eick (68) reported on the disposal by spray irrigation of wastes from the one tannery in Pennsylvania. Beam house wastes containing 6,300 lb of lime slurry constitute about 85 per cent of the 420,000 gal of waste discharged each day. Prior to 1951, the wastes were treated by primary sedimentation which removed about 84 per cent of the suspended solids and 58 per cent of the BOD. Since 1951, progressively greater amounts of waste have been pumped from lagoons and sprayed on land. At present 132 spray heads covering 15 acres of land are used to dispose of all the wastes between May and November. Bits of flesh and hair, which tend to clog the spray heads, are removed by a vibrating screen. The soil is disc-harrowed about once each three weeks.

Kubelka and Holamek (130) reported the results of experiments on various methods of tannery waste treatment. They found that plain sedimentation is usually not adequate treatment. Coagulation with alum and sulfuric acid at pH 7.0 gave better results. Treatment with $FeSO_4$ without neutralization is possible only if the waste is first oxidized with chlorine. The sludge produced from these processes can be dried on beds and contains 10 per cent calcium oxide and 2 to 3 per cent nitrogen. The sludge cannot be burned, but can be used as a fertilizer after mixing with manure and stored for several months to decompose the tannin. Anthrax spores settle out in the sludge and are destroyed or inactivated by this treatment.

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TEXTILE AND WOOL SCOURING WASTES

Souther and Alspaugh (205) reviewed the methods of reducing and treating textile wastes. They presented the results of pilot plant studies of lagooning, chemical treatment, and biological treatment. The studies showed that textile wastes can be treated satisfactorily in a number of ways. The authors concluded that: lagoons can best be used as flow and load equalizers before secondary treatment; chemical treatment is in general too expensive; and highly alkaline textile wastes can be treated better biologically if they are combined with domestic sewage.

British pilot plant studies, reported by Greene (94), also proved that a mixture of domestic sewage and textile wastes may be treated satisfactorily by biological methods. In the British studies, a mixture of wastes containing 3 parts domestic sewage to 2 parts textile waste was treated most effectively by alternating double filtration. This method of treatment was found to be more effective than single filtration or recirculation of effluent. Pilot plant studies of the activated sludge process were also conducted but were abandoned because of sludge bulking.

Nemerow (168) reviewed the theories of color formation by commercial

dyes and classified the dyes on the basis of their chemical structure. The azo group of dyes comprise about one-half of the commercial dyes. Methyl orange, a mono-azo dye, was used in experimental studies. The dye was treated by four methods: methoxylation, alkali, reduction with $SnCl_2$, and salt. Treatment by methoxylation resulted in no color reduction. Treatment by alkali reduced color intensity by 75 per cent. Reduction with $SnCl_2$ reduced color intensity 97 per cent. Treatment by salt reduced color intensity by 99 per cent.

Kehren and Denks (120) in the continuation of a previous article on the treatment of dye effluents with iron salts, discuss the various dye classes, the theories of their behavior, the behavior of iron ions in solution, and the mechanism of dye absorption. In the concluding article (121) of the series they describe methods of chemical analysis applicable to iron and dye containing effluents.

A process (51) for treating the wastes from the scouring of wool by a nonionic detergent was patented. In the process the wastes are coagulated with alum, settled, and the effluent discharged or treated with alkali to adjust the pH to 7.0, further clarified, and re-used. The full treatment reduced the BOD by more than 90 per cent. Grease may be recovered from the sludge. The process may also be applied to wastes resulting from soap scouring if they are acidified prior to coagulation.

Anderson (7) reported on an aeration process, proposed by Evans and Ewers in 1953 for the recovery of lanolin, that has now been tested on an industrial scale. With the particular type of flotation cells used, 40 per cent of the lanolin was recovered. The efficiency was greatly reduced by the use of excessive amounts of soap. In laboratory tests, recovery of lanolin was reduced from 55 per cent to 15 per cent when the soap content was increased from 0.05 per cent to 0.4 per cent. Churning the hot scour liquors also caused a drop in recovery. The addition of 0.1 per cent calcium chloride to liquors containing excessive soap increased recovery from 27 per cent to 40 per cent.

Buswell and Mueller (33) proposed the application of anaerobic fermentation for degreasing raw wool. In laboratory digestions seeded with sewage, 68 per cent of the grease in raw wool was fermented. The wool fibers removed from the fermentation vessel showed no evidence of disintegration.

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RADIOACTIVE WASTES

General

A bibliography covering the literature on radioactive waste processing and disposal was prepared by Frost (86) and covers both the classified and unclassified literature. Culler and McLain (52) have reviewed and compiled much of the available information on the high-level waste problem, including sources, amounts of wastes that will be produced, associated hazards, transportation, waste processing, and waste disposal.

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Fuel Reprocessing

Much progress has been made on the reduction of waste volumes by reuse of reagents and backcycling of waste streams according to Lawroski (137). Volatility and pyrometallurgical processes are being pursued and the latter will compete with solvent extraction by the end of the next decade. Solvent extraction will be used most extensively through about 1962. Pyrometallurgical processing includes oxide drossing for core material as one type of process and molten metal extraction for blanket material as the other. There are at least five major projects under way to find ways to immobilize wastes as more or less non-leachable solids as a more satisfactory long-term solution to the problem of tank storage. It is also expected that considerable progress will be made in determining control limits for quantities of waste discharges to the environment.

The processing of spent fuels from power reactors is discussed by Nicholls and Spence (169). They propose that moderate decontamination of 10^2 instead of 10^8 is sufficient for power reactors since they will operate at high burnup and will not produce weapons materials. Effect of HNO_3 on corrosion of different types of stainless steel at 300°C and 1,500 psi is reported (119). The use of a quartz liner was suggested. Some work with $Al(NO_3)_3$ precipitation and $Sr_2(SO_4)$ solubility in H_2O and HNO_3 at various temperatures was reported (119).

Studies are continuing with the projected pyroprocessing refabrication experiment (164) and with the pyrometallurgical reprocessing experiment (201).

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Heterogeneous Reactors

Heterogeneous reactor reprocessing problems are discussed (23) primarily from the viewpoint of a central station solvent extraction reprocessing station. Primary emphasis is placed on a de-

scription of alternate methods for converting fuels to a nitric acid soluble form and the effects of radiation and inert alloy metals on the solvent extraction method. Head end methods include acid dissolution, oxidation, hydrochlorination, chlorination, carburization, molten metal dissolution, and electrolytic dissolution. A new reprocessing method, the Hermex process, which uses mercury as the dissolving agent, is also presented. Two new methods, Darex and Zirex processes, for converting fuels fabricated of HNO_3 insoluble metals to HNO_3 solutions suitable for reprocessing by solvent extraction, are described (188). An unconventional approach to fuel element processing is proposed (109) in which a heterogeneous reactor lattice can be constructed at randomly packed bare uranium fuel elements which may be slowly dissolved in the coolant. The resulting solution would be processed on a continuous basis.

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Homogeneous Reactors

Ferguson (78) describes a procedure for the chemical processing of a thorium breeder reactor of the two region aqueous homogeneous type consisting of the following operations: concentration of insoluble fission and corrosion products from the core system into a small volume of fuel solution; combining this slurry with irradiated ThO_2 slurry taken from the blanket; recovery of D_2O by evaporation; dissolution of the Th and U in HNO_3; and, after a suitable cooling period, recovery of the U and Th by solvent extraction for return to the reactor. Hydroclones were successfully demonstrated on dynamic loops for concentrating insoluble fission and corrosion products under simulated reactor conditions. The behavior of I_2 in aqueous homogeneous reactor systems was reported (182). Gas stripping, adsorption of I_2 from off-gases in the low pressure recombiner catalyst bed, and the use of CuO as solid sorber in a high pressure system were investigated.

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Thermal Breeder Reactors

Bruce (28) discussed the principles of thermal breeder reactor fuel and blanket processing.

Uranium Recovery

Clouse *et al.* (45) describe the facilities at the Gaseous Diffusion Plant, Oak Ridge, Tenn., for the recovery of U from recycled cleaning solution and from miscellaneous waste solutions containing variable concentrations of impurities. The recovery operations are carried out in two separate systems: the mixer-settler system and the general recovery system. Descriptions are given of the two systems and the actual quantities of U recovered by each.

An amine type extractant in kerosene offers the most advantages from a practical point of view in extracting uranium from sulfate leach liquors (19). A process has been developed for the recovery of uranium from slag scrap (115). It consists of the follow-

ing steps: roasting and grinding of the scrap material, leaching with HCl to solubilize the U, precipitating the U from the filtered leach liquors as $UO_2NH_4PO_4$, and converting the $UO_2NH_4PO_4$ to $Na_2U_2O_7$ by slurrying of the former with a NaOH solution. The advantages and disadvantages of solvent extraction and fractional distillation of fluorinated derivatives for U and Pu are discussed by Isaac (110). Wymer and Blanco (234) report a study of the nitric acid and caustic systems as applied to uranium-aluminum alloy dissolution. A non-aqueous process (41) for the recovery of U from spent fuel consists of dissolution of the fuel element in a fluoride melt by hydro-fluorination at 600 to 700°C, direct fluorination with fluorine for the production and volatilization of UF_6, with further decontamination of the product UF_6 absorption-desorption step. Good decontamination is obtained in the fluorination step due to the low volatility of most of the fission product fluorides. An over-all decontamination factor of greater than 10^6 with adequate U recovery has been demonstrated in laboratory scale tests. Six pilot runs utilizing the fluoride volatility process for the decontamination of irradiated U are described in detail (159). Charlesworth (43) prepared a preliminary design and cost estimate for a dual-purpose processing plant capable of processing 1,500 lb U or 8.09 kg of Pu, as Pu-Al alloy daily. It was estimated that the integration of U and Pu processing by the use of the same process equipment for both types of fuels results in a saving of 21 per cent in capital cost and 28 per cent in operating cost as compared to the use of separate facilities. Fused fluorides can remove all but a trace of Pu and 95 to 100 per cent fission products (except Ru) from molten U (34). Decontamination was less than that obtainable with aqueous processing but would be sufficient for fast breeders.

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Rubino, E. M., "Radioassay of Products from Precipitated Phosphatic Materials." U. S. Atomic Energy Comm. Rept. MITG–220 (Sept. 6, 1949).

Thorium Recovery

Potter (181) describes a study made of the distribution of the principal fission products, Pa and U, between tracer level Th (3 per cent by weight)-U and certain oxides, carbides, sulfides, and nitrides. The highly volatile elements Cs and Sr are removed from the metal to the extent of 70 to 100 per cent; 30 to 90 per cent of the less volatile elements Ce and other rare earths are removed from the metal. Most of the Zr, Ru, Pa, and U remain in the alloy. The feasibility of removing fission products from irradiated Th-U alloys by using a zone melting process was described (29). This procedure utilizes an electric arc to maintain the molten zone. U, Te, Zr, and Ru were successfully moved in the direction of zone travel and some of the fission products were removed during processing by volatilization.

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Plutonium Recovery

A mixture containing Pu, U, and fission products is dissolved in HNO_3, $Bi(NO_3)_3$ and $Zr(NO_3)_4$ are added as carriers, and phosphate is added to precipitate insoluble phosphates of Pu, Zr, Bi, and Nb (222). Pu phosphate may be separated from the zirconium phosphate on which it absorbs by leaching with greater than 7 N HCl after the mixture of phosphate is treated with dilute HCl which puts the $Bi(PO_4)_3$ in solution. In another procedure (26), the U is separated out as $U(CO_3)_2$ by addition of solid $NaHCO_3$ at a pH of 2.7 to 3.0, the pH is adjusted to 6.5 with more bicarbonate, and a water solution of La is added, causing a precipitate of $La(CO_3)_3$ to form, which carries the Pu^{+3}. After filtration and dissolution, the Pu is oxidized to the hexavalent state, adjusted to pH 6.5, and another $La(CO_3)_3$ precipitate forms carrying fission products carried in the first precipitation. The hexavalent Pu remains in the scavenged solution. A modification of this procedure (106) calls for the oxidation of the Pu to the hexavalent state, carbonate ion is added to complex the Pu, and an aqueous solution of an La salt is added to remove Ba, Zr, and Nb, the hexavalent Pu being unaffected. The Pu is reduced with a reducing agent which does not affect uranyl ion, and the Pu is removed by formation of a bismuth hydroxide carrier precipitate. Morgan (162) describes still another procedure for separating Pu from U and fission products.

Solvent extraction with 30 volume per cent tributylphosphate (TBP) and 70 volume per cent kerosene was used to separate Pu and U from fission products (59). The Pu was reduced and stripped into the aqueous phase by aqueous hydrazine solutions. A final washing with TBP-kerosene removed most of the U, and this was followed by centrifugation for complete separation of the layers.

Aikin (3) presents a pilot plant ion exchange operation for the separation of irradiated Pu from U. He claims that a small ion exchange unit can be put on a competitive basis with large solvent extraction units.

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Waste Handling

Tank Storage

High-level radioactive wastes are being stored in tanks. Platt (180) reports that the high-level wastes from HAPO fuel processing operations are stored in steel lined, reinforced, concrete tanks of 500,000 to 1,000,000 gal capacity equipped with external condensers which remove the heat produced by radioactive decay. These tanks can be built in dry sand for about 25 to 40 cents per gal. At the Savannah River Plant, because of the more restrictive environmental conditions, a cup and saucer arrangement is utilized in constructing tanks with a capacity of 750,000 gal to insure safe collection of any leakage. These tanks, built of steel and concrete, cost about $1.00 per gal. At the Idaho Chemical Processing Plant 300,000 gal stainless steel tanks were provided at a cost of approximately $2.00 per gal. Storage in structural tanks has a number of limitations including finite capacity, uncertain durability, vulnerability to accidents, and significant cost. The very long-term storage required for cesium, strontium, and plutonium concentrates focuses attention upon the

problems of structural disintegration due to corrosion, chemical action, and long continued exposure to radiation. Tank storage has the advantage, in the present state of limited knowledge, of keeping the wastes under control and in a known location. Manowitz and associates (151) describe pilot plant and laboratory studies and concepts for design of containers (35) for concentrated Savannah River reactor fission-product wastes. Wilson (230) describes the type of tank provided for storage of alkaline radioactive waste at Savannah and reports that the primary tank has a total capacity of 1,070,000 gal, is of steel construction, and is contained in a secondary unit for leak protection. A reinforced concrete shell protects the two containers from soil pressure and exterior corrosion, supports the earth shielding, and serves as a third barrier to the escape of wastes.

The types of facilities provided to remove the heat of decay from high-level waste storage facilities were described by Platt (180). Coppinger and Tomlinson (49) suggest that the removal of cesium and strontium from high-level wastes will markedly decrease the time that the self-heating characteristics remain as a practical operating problem and pave the way for the eventual storage of the residual wastes by ion exchange in the soil. The problem of heat loss from the bottom of an asphalt-lined waste disposal pit is considered by Jury (117). He concluded that the heat loss is negligible compared to the rate of heat generated during decay.

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Chemical Precipitation

A synthetic effluent was treated in a sludge blanket precipitator with 80 ppm PO_4 and 40 ppm Fe^{+3} at a pH of 11.5, then passed through soil columns for additional removal of radioactivity (195). The precipitator accounted for a removal of 95 to 96 per cent of the activity, with the residual containing 40 per cent Ru and 60 per cent Cs. All of the Cs and most of the Ru were removed in the columns, resulting in over 99 per cent removal of all of the radioactivity. By employing long columns, or columns in series, a decontamination factor of 10^3 can be achieved. Defects noted with Nuneham Courtenay Greensand could be partially remedied by conditioning with electrolytes. Vermiculite is being tested as an alternative column adsorbent. Tests, conducted on the use of two precipitators in series with the second employing a ferrous sulfate "blanket" to remove Ru, show very promising results. An extension of these studies to pilot plant scale (196) shows decontamination factors of 600 to 1,000 with a synthetic waste. The process consists of treatment in a sludge blanket precipitator with 80 ppm PO_4 and 40 ppm Fe^{+3} at a pH of 11.5, followed by another precipitation at the same pH, using 20 ppm Fe^{-2} and 20 ppm S^{-2}. The effluent is finally passed through a column of crude vermiculite. The phosphate treatment removed 94 per cent of the activity. This was increased to 98 to 99 per cent by the sulfide precipitation. The chief effect of the sulfide treatment is to remove most of the radiocolloids, especially of cerium. The over-all decontamination would not be greatly reduced if the sulfide precipitation were omitted, but it acts as a safeguard in case of difficulties in the column treatment.

Scavenging operations at Hanford for precipitating Sr^{90}, Cs^{137}, and Pu^{239} are described by Platt (180) preparatory to releasing the wastes into the ground. $Ni_2Fe(CN)_6$ is utilized for concentrating Cs^{137}, and $Ca(NO_3)_2$ or $Sr(NO_3)_2$ for Sr^{90}; Pu^{239} is decontaminated as a hydroxide, sulfate, or phosphate in neutralized solutions. Decontamination factors of 200 to 1,000 are reported for cesium and 50 to 700 for strontium. Burns and Stedwell (31) indicate that to accomplish these decontamination factors these elements were precipitated at pH 9.5 by the addition of sodium ferrocyanide, strontium nitrate, sodium hydroxide, and nickel sulfate. Co^{60} is carried from aqueous waste solutions as a mixture of insoluble cobaltous and ferrous cobalticyanides after the cobaltic amine complexes have been destroyed by reduction and acid deammoniation. Approximately 99.9 per cent removal from the solution is reported (189). Ruthenium is removed from solution by distillation of the tetroxide. Removals of 85 to 99 per cent have been effected using strong oxidants such as chlorine, ozone, potassium permanganate, and sodium bismuthate (65). Magnesia was reported to be most effective in neutralization and precipitation of solids from uranium refinery process wastes (184).

Lowe (145) was granted a patent on a process for the decontamination of radioactive solutions. The process includes initial adjustment of the pH to 1.0 and addition of Na_2S to pH 4.0. $FeSO_4$ is then added and a precipitate of FeS is formed. The solution is adjusted to pH 10 with NaOH and some of the residual ferrous ion is precipitated as $Fe(OH)_2$. $Ca_3(PO_4)_2$ is formed by the addition of $CaCl_2$ and an alkaline phosphate. This three-pronged procedure results in a decontamination of about 10^3 and a sludge having half the volume of that produced by other methods.

The chemical treatment plant which will employ lime soda ash softening for the reduction of low-level wastes discharged into White Oak Creek and the Clinch River has been described (171).

The treatment facilities provided for treating the wastes at the Atomic Weapons Research Establishment, Aldermaston, England, include single- or double-stage coagulation and sedimentation units, followed by pressure filters, sludge-canning facilities, and evaporation facilities (231). The system designed for the discharge of effluent to the River Thames is also described.

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Biological Treatment

Harmeson and Dietz (101) conclude that P^{32}, I^{131}, and S^{35} in concentrations of 110 μc/l have no apparent effect on normal sludge digestion. Concentrations up to 200 mc/l can be reached before the inhibitory effect on anaerobic digestion becomes significant. Fission products exhibited inhibitory effects on digestion during the 30-day digestion period. P^{32} and S^{35} appeared to concentrate in the sludge, whereas I^{131} appeared to concentrate in the liquid component. With initial concentrations of U of 0.098 to 2,000 mg/l and salinity approaching sea water, Gloyna and Ewing (90) report 60 to 90 per cent removal of U by biological slimes during continuous operation. Rubidium-86 was adsorbed within a trickling filter bed and slowly leached over a period of about 37 hr after dosage (83). The adsorbed radioactivity was associated with the zoogleal mass growing on the filter rock.

Ion Exchange

Ion exchange resins are used to reduce the total solids content of the primary coolant stream flowing through reactor cores. The level should be less than 0.5 ppm (22). Resins are also used as a by-pass cleanup unit in the primary coolant water loop to remove built-up radioactivity. These resins become highly radioactive and are disposed of by burial rather than being regenerated. Roland (186) has described the use of ion exchange resins in uranium extraction, uranium purification, reactor water treatment, zirconium purification, and waste disposal. Resin from such plants is not regenerated, but disposed of as a solid contaminated material, or incinerated, thus further concentrating the activity. Kunin and Preuss (132) review the utilization of ion exchange processes in the atomic energy field and refer to the use of mono-bed ion exchange in the removal and concentration of radioactivity from reactor cooling water, in the experimental treatment of condensates from the evaporation of high-level wastes, and in the recovery and purification of radioactive isotopes. The application of ion exchange membrane cells for the neutralization and recovery of nitric acid from solution of mixed fission products is described and

the use of mixed-bed ion exchange processes for the decontamination of drinking water supplies contaminated by fallout is mentioned. The removal of radioactivity by mixed-bed ion exchange at Argonne National Laboratory has been very nicely reviewed by Swope (213). Her experimental studies showed that highest decontamination factors were obtained in removing old mixed fission products from tap water when the water was adjusted to pH 2.5 with nitric acid. This adjustment increased the anion content of the water and a 3:1 ratio of anion to cation is recommended. Flow rates should not exceed 2 gpm per cubic foot of mixed resin. The capacity of a mixed-bed exchanger for the removal of radioactivity is based on the amount of total dissolved solids in the feed—the lower the dissolved solids content the larger the throughput.

In the resin and pulp process for recovery of U from ores (10)(186), resin-filled baskets oscillate in the slime pulp, thus eliminating slime removal stages. Sulfuric acid is leached, MnO_2 oxidized pulp is adjusted to a pH of 1.7 and treated with $FeSO_4$ to reduce the V to VO_4^{-3}. After adsorption the U is precipitated from eluted liquor as magnesium ammonium diuranate. Studies on the adsorption of Pu on Dowex-1 were reported (199). Pu^{+3} was not adsorbed, but Pu^{+4} could be adsorbed and stabilized by $NaNO_2$.

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Solvent Extraction

The use of liquid-liquid extraction for the removal of the major long-lived fission products from a simulated acid aluminum nitrate waste was reported by Krieger *et al.* (129). Tributyl phosphate, di-2-ethyl hexyl phosphoric acid, tridecyl phosphine oxide, tri-n-octylamine, and thenoyl trifluoroacetone were found to be effective for the removal of one or more of the cerium, yttrium, zirconium, niobium, and ruthenium tracers used. After converting the ruthenium and niobium to an extractable form, more than 99 per cent of the tracers was extracted with undiluted TBP. Cesium was not extracted and strontium was very slightly extracted. The extracted radionuclides were stripped from TBP with water, dilute hydrofluoric acid, and nitric acid; thus permitting reuse of the organic phase. Considerably greater stage extraction efficiencies were reported under the influence of ultrasonic treatment (2). Efficiencies of 52 per cent with the non-ultrasonic control were increased to approximately 99 per cent when subject to ultrasonic treatment.

Calcination

Brookhaven National Laboratory (152) has developed a pilot plant model "continuous calciner" for substantially reducing the volume of high-activity aqueous waste streams. This unit consists of a heated-tube auger-agitated concentrator which dehydrates and fuses the various aqueous salt solutions to an anhydrous free-flowing melt on a continuous basis. A decontamination factor of approximately 1,000 is reported. Three types of leaching procedures (non-continuous, non-agitated, and a continuous system with mixing) were investigated (1)

for the recovery of Sr^{90} and Cs^{137} from Redox-Al-type and STR-Zr-type wastes. Grimmett (95) has investigated the conversion of aqueous aluminum-type reactor fuel wastes into a free-flowing granular aluminum oxide solid by means of a fluidized bed calciner under varying conditions of feed rate, temperature, and operating time.

Waste Disposal

Several papers appeared during the past year describing the over-all waste disposal problem in general or referring to operations at specific sites. The over-all problem of radioactive wastes was discussed by Kenny (122), and from the standpoint of the AEC by Wolman (232), Lieberman (142), Whipple (229), and Straub (208). Gorman (91)(92) discussed the interrelationship of site selection and waste disposal.

Farmer (73)(74) reviews the techniques developed at Windscale for handling the radioactive liquid and gaseous effluents. The facilities at Windscale for handling the different categories of wastes (including treatment, storage, and disposal practices) are described. The release of activity into the Irish Sea is defined and the effects observed over a four-year period are detailed. British practice is also reviewed by Burns and Glueckauf (32), particularly with respect to the situation at Harwell. There a three-pronged approach is being considered for effluent control and disposal, including alkaline phosphate treatment in upflow sludge blanket-type basins, filtration through vermiculite, and further treatment by electrodialysis. The aim is to produce a process water sufficiently low in activity and of adequate chemical characteristics to serve as a process water, thus reducing the volumes of waste released to the environment. High-level waste treatment would be accomplished by evaporation, followed by fixation in ceramics. According to LaPointe (135) the facilities at Shippingport utilize natural decay, concentration and storage, and dilution for waste disposal. Another report (62) summarizes the criteria established by the Pennsylvania Department of Health in regard to radioactive materials to be discharged from this plant. A level of 10^{-8} μc/ml is established in the Ohio River for all isotopes except tritium. A separate permissible discharge level was established for this radioisotope. Terrill and Hollis (214) describe the various classes of wastes produced in the operations at this plant and Straub (207) referred to the facilities provided for waste disposal at Shippingport as a basis for facilities for the Yankee Reactor at Rowe, Mass., which will be similar in design but of larger energy output.

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Sewer and Stream Discharge

The hazards to sewage works personnel arising from the present rate of discharge of radioactive materials from hospitals and industrial and research establishments into sewers were ably presented by Kenny (123). Radiations from radioactive isotopes adsorbed on sewer walls and sewage treatment equipment, and from crude sewage and sewage sludge, were shown to be below the accepted safety levels.

Forrester (81) indicates that the big volumes of diluted and only slightly contaminated waste solutions are the potential source of contamination of sewers, rivers, lakes, and estuaries. Three distinct types of stream samples (water, mud, and aquatic biota) are all of importance, each yielding information not derivable from the other two. No one type should be neglected if an adequate interpretation in terms of extent and effects of stream contamination is desired. A great deal of information can be obtained in a brief, intensive survey of approximately 10 days duration. On the other hand, seasonal variations of temperature, stream flow, predominant biological species, etc., may be of importance, requiring either an extensive, long survey or a series of briefer field studies. Tsivoglou and associates (219)(220) review the effects of pollution of streams by radioactivity, the methods of controlling such pollution, and the techniques used for detecting radioactivity in water, aquatic organisms, and mud. They describe the organization and planning of stream surveys for radioactive contamination, the equipment needed, and the methods of sampling. The importance of determining background activity in the unpolluted reaches of the stream and of obtaining adequate hydrologic data is stressed.

Gross radioactivity measurements in the Columbia River were made for alpha and beta activity and reported by Clukey (46)(47). Activity levels were also reported for bottom mud samples. Norton (170) pursued a theoretical and empirical approach toward defining the turbulent diffusion process encountered in the Columbia River. No solution could be found for the differential equation encountered in the theoretical development. The empirical approach yielded an adequate fit to the available data. The elimination of second stage hold-up prior to the release of radioactive wastes to the Mohawk River is reported by Truran (218). The fluoride monitoring program initiated in August 1954 by the Goodyear Atomic Corporation in the Portsmouth area has continued (30) and the results obtained are compared with those reported in two surveys conducted by the U. S. Public Health Service prior to operation of the plant. There seems to be no increase in fluoride content as a result of the Portsmouth operations.

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Ground Disposal

The National Research Council, National Academy of Science, has released a report on the disposal of radioactive wastes on land (166). Wastes may be disposed of safely at many sites in the U. S., but, conversely, there are many large areas in which it is unlikely that disposal sites can be found, for example, the Atlantic Seaboard. Disposal in cavities mined in salt beds and salt domes is suggested as the possibility promising the most practical immediate solution to the problem. Disposal could be greatly simplified if the waste could be converted into solid form of relatively insoluble character. Injection of large volumes of dilute liquid waste into porous rock strata at depths in excess of 5,000 ft may become feasible but means must first be developed for making the waste solutions compatible with the mineral and fluid component of the rock.

Amphlett (5) has discussed the various methods that may be utilized to fix the activity from highly active wastes in solid form. These include fixation by ion exchange followed by firing, combined calcination and ion exchange, and conversion to unleachable glasses, melts, or ceramics prior to disposal into the ground. He concludes that the ceramic process offers a number of advantages over the ion exchange method. In another paper (6) he indicates that by incorporating radioactive solutions into mixtures of waste solutions and soil, glasses are formed on heating to temperatures of approximately 1,000°C. These glasses are highly resistant to leaching by water. Only Ru volatilizes appreciably during the firing process. Experiments utilizing various shales from the Conasauga formation, Oak Ridge, Tenn., for the removal of activity from water were described (12). As treatment with shale leaves the water turbid, the water should be coagulated with a polyelectrolyte, settled, and filtered. Removals of 95 to 99 per cent were reported. Davey and Scott (56) describe studies on the absorption of U on clay-like minerals (montmorillonite, vermiculite, and halloysite).

Three of the five surface pits used at Chalk River for the disposal of fission products wastes (174) are contributing to the contamination of swamps in the disposal area. The streams and a lake receiving the drainage from these swamps show Sr^{90} contamination below the drinking water tolerance concentration. Oak Ridge National Laboratory reports (172) that 5.6×10^6 gal of radioactive waste containing 5.8×10^4 curies of Cs^{137} and 1.5×10^4 curies of Ru^{106} have been added to the three surface pits up to December 31, 1956. The waste stream released to the pits contains, on the average, 16.3 mg/ml of Na and 23.8 mg/ml of NO_3, which account for 70 per cent of the total solids. Ewing *et al.* (72) studied the effect of length of travel through porous medium on the breakthrough of a cationic trace component, the effect of gross waste composition upon certain commonly used equilibrium parameters, and the application of data obtained by laboratory studies to field scale operation of a waste injection system. Their results showed that the soil had a greater affinity for cesium than for calcium and strontium. From their studies, Orcutt *et al.* (175) conclude that the feasibility of employing underground formations for the retention or permanent storage is dependent on the chemical and physical compatibility of the waste with the receiving formation and on the degree of certainty of predicting the velocity and direction taken by the more hazardous components of the waste.

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Ocean Disposal

Packaged radioactive wastes have been disposed of at selected ocean disposal sites since 1946. Joseph (116) has described these operations including a summary of the types of packages used and the places where the wastes are dumped. At Windscale (75) the wastes are treated with alkali to give a pH value of 8.0, coagulated with alumino-ferric or ferric sulfate and soda ash, filtered through pressure sand filters, and, if necessary, given further treatment by coagulation and filtration before discharge to the Irish Sea. Effluent results show a removal of about 80 per cent of the activity which is predominant in Ru. It is also reported that wetting agents and citric acid interfere with plant operations. Surveys have been made since 1950, when the plant was placed in operation, and show no harmful effects due to discharge of liquid wastes into the sea. At Dounreay, the site of the fast reactor, the condensate from the evaporation of reprocessing wastes will be discharged to the sea after monitoring (8)(14). A tunnel will convey the low-level radioactive wastes to sea. It will terminate in a dispersal chamber under the sea bed and effluent will be discharged by pipes passing through the roof of the chamber.

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Incineration

Harris and Weinstein (102) report the results of their experiments with open field burning of up to 10 tons of contaminated laboratory wastes containing millicurie amounts of activity. Extensive sampling of the area, out to a distance of 2,000 ft, revealed negligible contamination of the air and negligible fallout under the conditions of test.

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Economics

As has been reported, Platt (180) gave data on the cost of tank facilities at Hanford, Savannah, and Idaho. In addition, he reported some data on the

cost of chemical scavenging for the separation of cesium and strontium. McEwen (156) compares costs of evaporation vs. coprecipitation (FeS process) for the concentration of liquid reactor wastes prior to burial. Data indicate that the FeS process competes economically with evaporation when the dissolved solids in the feed reach 1 to 3 per cent, and that the economic advantage of coprecipitation becomes very pronounced in processing high-solids-content wastes. Zeitlin, Arnold, and Ullmann (235) published data on the relationship of required processing capacity, build-up of fission products, and accumulation of liquid wastes, based on a predicted nuclear power economy growth rate. They report that by the year 2000, the accumulated fission product activity will be greater than 3×10^{11} curies. To dispose of it, they estimate that costs of $1.60 to $64 per gal will be permissible for the predicted nuclear power economy. Ullmann and Arnold (221) state that to determine optimum fuel cycle, the cost of storing spent fuel elements must be balanced against processing, refabrication, and shielding costs.

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JOHN K. HOSKINS

John K. Hoskins, Past President of the Federation, died at Chevy Chase, Md., on May 16. The "Chief," as he was known to his associates, was Federation President in 1945–46, and was the recipient of the Kenneth Allen Award in 1943. Mr. Hoskins served the Federation as a Director on the Board of Control for the period of 1942–44.

Mr. Hoskins was born July 12, 1884, at New Holland, Pa., and received a B.S.C.E. in 1905 from Pennsylvania State College. He studied further at the University of Berlin. In 1910 he received the degree of Civil Engineer.

Mr. Hoskins joined the U. S. Public Health Service in 1913, and climaxed a distinguished career in sanitary engineering with his appointment as its first Chief Sanitary Engineer in 1943. He served in that position until his retirement in 1948.

He was a member of the American Public Health Association, American Association for the Advancement of Science, American Water Works Association, Conference of State Sanitary Engineers, Federal Sewage Research Association, and Institute of Sewage Purification.

The "Chief" was a real pioneer in the formative era of sanitary engineering and stream pollution control. His mark will long serve as an example for others to follow.

Sewage Works

EFFECTS OF SYNTHETIC DETERGENTS ON SEWAGE TREATMENT PROCESSES*

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It is not the purpose of this paper to review in detail the extensive literature which has developed on syndets in relation to sewage treatment, but rather to present some new information and attempt an extrapolation of available data to predict how increased consumption of syndets and diminishing use of soap is likely to affect sewage treatment processing in the years ahead.

Studies have been conducted by several investigators in the M.I.T. laboratories over the past five years. It is largely from this fund of information, and personal experiences at several treatment plants at widely scattered parts of the United States, that this appraisal is attempted. The discussion divides itself naturally into considerations related to primary treatment, secondary treatment, and the receiving stream.

Primary Treatment

Primary treatment is generally considered to entail solids separation by means of combination sedimentation-flotation units and disposal of the separated solids. Consequently, suspended solids and grease removals are important considerations. In addition, removal of syndets in such facilities is of some significance insofar as their presence may affect sludge disposal practices.

Suspended Solids Removal

There are numerous suggestions in the literature indicating that the presence of syndets has had a serious effect on decreasing the efficiency of sedimentation units. Degens *et al.* (1) have conducted extensive studies and concluded that syndets have little if any effect. McCarty (2) has explored the effects of syndet concentrations that might be expected in the future in Boston sewage and has found no significant effect on suspended solids removal (Table I).

Grease Removal

Many reports have indicated that grease removals by primary units have suffered considerably due to the increasing consumption of syndets. Unfortunately, not many sewage treatment plants run grease determinations routinely, so such statements are usually based on rather meager data or plain speculation.

In this appraisal there has been occasion to review the operating records of several United States plants. One of the larger plants makes frequent determinations of grease removals accomplished by the primary sedimentation tanks. During 1951, 1952, 1953,

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TABLE I.—Effect of Syndets on Suspended Solids and Grease Removals by Sedimentation

Tide Added (mg/l)	Susp. Sol. in Effl. (mg/l)			Grease in Effl. (mg/l)		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
0	30	32	89	21.1	17.9	89
10	31	26	86	23.4	18.5	94
25	35	31	93	22.5	19.2	102
50	31	32	92	24.0	19.7	106

and 1954 grease removals averaged 50, 46, 38, and 43 per cent, respectively. For some reason grease removal studies were not made during 1955 and 1956. They were resumed again in 1957 and for the first six months of the year averaged 57 per cent (see Table II). Monthly averages obtained within the respective years have varied widely. Thus, there appears to be considerable question in regard to the claims made that syndets are responsible for larger and larger amounts escaping through primary units.

McCarty (2) studied grease removal in Boston sewage and explored the possible effects of high concentrations of syndets that may be anticipated in the future. The results of his studies, shown in Table I, indicate that some decrease in grease removal efficiency does occur with increased syndet consumption, but the decrease is probably too small to be indicated by routine plant sampling programs under natural conditions where plant operation is affected by many variables which cannot be controlled.

Syndet Removal

Because surfactants chosen for syndet formulations are highly soluble in water and are not precipitated by calcium and magnesium ions, it is highly improbable that significant amounts are removed in sedimentation-flotation units. Due to their surface active properties, however, some fraction should be separated by adsorption on the surface of settleable solids. Measurement of this fraction is extremely difficult because present test methods are incapable of measuring all types of surfactants and many are of questionable accuracy in a sewage medium. Reports have indicated removals in primary units from as great as 50 per cent to as little as 10 per cent.

TABLE II.—Grease Removal by Primary Sedimentation Tanks at a Major U. S. City

Year	% Removal
1951	50
1952	46
1953	38
1954	43
1955	—
1956	—
1957 (6 mo.)	57

Inasmuch as the removal of surfactants in primary units is generally considered to be largely a result of adsorption phenomena, it is reasonable to assume that percentage removals will be a function of concentration. Pescod (3) made a study of removal of alkyl benzene sulfonate (ABS) in Boston sewage. He employed the Fairing-Short (4) modification of the methylene blue method, which is highly specific for ABS, to obtain his results.

A summary of his findings (Figure 1) shows that about 25 per cent of the 2 mg/l originally present in the sewage was removed during the sedimentation period. In samples to which ABS was added and flocculated for 1 hr prior to settling, the removals were below 10 per cent in all cases. Studies were made in a similar manner in which the suspended solids, hardness, and soap content of the sewage were varied, but the results were essentially

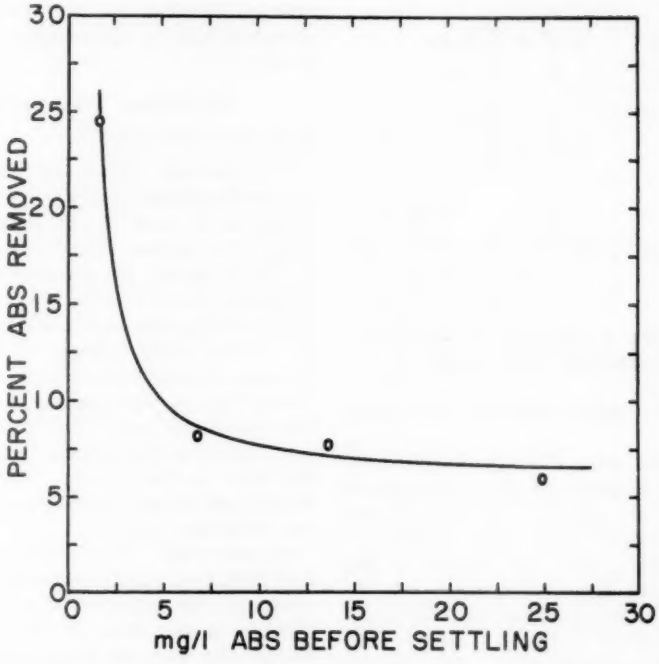

FIGURE 1.—Removal of ABS from Boston sewage by sedimentation.

the same. A slight increase in removals was noted when the polyphosphate and protein (peptone) content of the sewage was increased. Pescod concluded that when the ABS concentration exceeds 5 mg/l, removals will not exceed 10 per cent.

Sludge Disposal

Although the amount of syndets removed per unit volume of sewage in sedimentation units is very small, it should be kept in mind that, when it accumulates in the small volume of settled sludge, the concentration will be multiplied by a factor of 100- to 400-fold. Thus, removals of as little as 0.5 mg/l could be expected to produce concentrations of 50 to 200 mg/l in the sludge.

There appears to be no evidence to indicate that syndets have any detrimental effect on vacuum filtration of sludge. Weist (5) considered the matter, but came to no definite conclusions.

There have been no substantiated reports in the literature to indicate that syndets have been a cause of trouble in plant-scale digestion units, despite the fact that many instances of unsatisfactory digester operation have been described.

Several laboratory-scale investigations on the effect of syndets in sludge digestion have been reported. Many of these were made at an early date, before the development of some of the more popular present day surfactants, and results obtained should be evaluated with caution. Degens *et al.* (6) reported no interference with digestion at levels up to 500 ppm. Raybould and Thompson (7) showed serious interference with digestion at levels of 600 ppm of certain syndets. The interference was enhanced in the

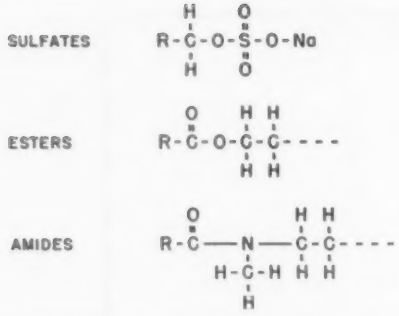

FIGURE 2.—Chemical structures of biologically "soft" syndets.

presence of polyphosphates and sodium sulfate.

Johnson and Bloodgood (8) have reported recently on their attempts to improve the digestion of vegetable oils by pre-emulsification with surface active agents. ABS was chosen as the emulsifying agent. Digestion was retarded by the presence of ABS. At the conclusion of the run, assays were made for residual ABS. The control digester was found to have 58 mg/l, derived solely from the sewage sludge, while the test digester contained 95 mg/l.

On the basis of the limited data available and because the limiting concentrations of certain surfactants in sewage sludge may be nearing, as indicated by Bloodgood and Johnson's studies, it would seem germane to recommend further investigations in this area.

Secondary Treatment

Biological Degradation

The normal course of events in aerobic stabilization of sewage involves oxidation of part of the organic pollutants to carbon dioxide and water, to obtain energy for conversion of the remainder to new biological cell tissue which can be removed from the water by settling units. Many of the surfactants used to formulate syndets lend themselves to this scheme of nature, but others do not. The former are referred to as biologically "soft" and the latter as biologically "hard" materials, soft meaning easily assimilated and hard the opposite.

Studies on the biological assimilability of surfactants have been conducted by numerous investigators. Notable among these is the work of Bogan (9) and Ryckman (10), who concentrated their efforts on the significance of chemical structure of the organic compounds. On the basis of their results, it has been established that surfactants classed as sulfates, esters, or amides are biologically "soft." The structural character of these compounds is shown in Figure 2.

The surfactants which have been

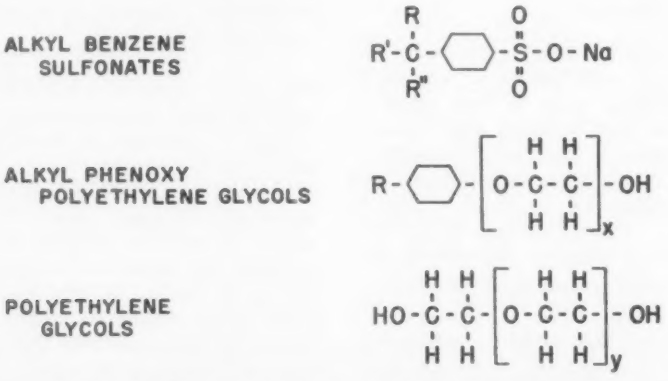

FIGURE 3.—Chemical structures of biologically "hard" syndets.

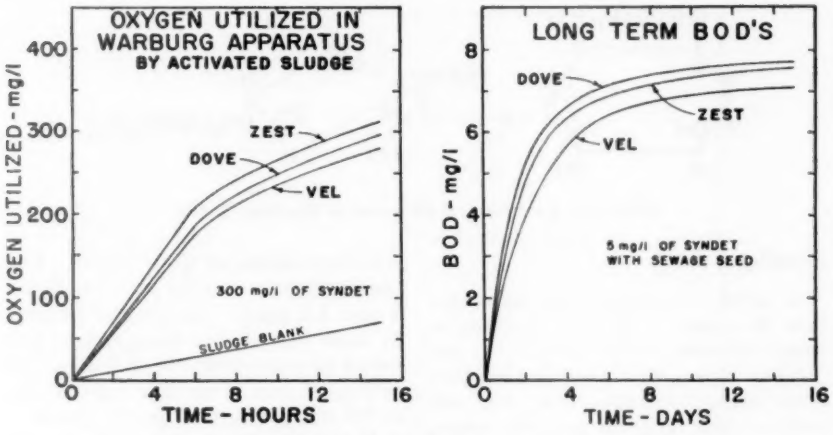

FIGURE 4.—Biological oxidation of "toilet bar" syndets.

found to be biologically "hard" are of three classes: alkyl benzene sulfonates (ABS), particularly the form having a branched alkyl group derived from propylene; alkyl phenoxy polyethylene glycols; and simple high-molecular-weight polyethylene glycols. The structural formulas of these compounds are given in Figure 3. Although some oxidation of these compounds has been noted, such oxidation is slow and, probably, limited to terminal groups. Undoubtedly, these compounds are responsible for the major difficulties attributable to syndets in secondary treatment units and receiving waters.

New Products

The producers of syndets are constantly putting new products on the market. These may be radically new formulations or they may be old formulations presented under a new name. Within the past year or so there has been a definite attempt to invade the toilet soap market with substitute "toilet bars" formulated from syndets. Three are currently being sold in the United States under the names of Dove, Vel, and Zest. Because the makers consider the composition of their bars a trade secret, it was decided to study the biological behavior of the new products. McCarty (2) subjected all three to BOD and activated sludge feeding studies. His findings, summarized in Figure 4, show that all are biologically "soft" or readily stabilized by organisms native to sewage. Activated sludge studies showed essentially complete degradation of the materials based on BOD and COD values of the influent and effluent. Frothing was not a serious problem with any of these products at concentrations up to 200 mg/l in the activated sludge feeding studies. It is concluded that the new "toilet bars" do not constitute a threat to secondary sewage treatment processes.

A new nonionic surfactant has reached the stage of commercial production. It is derived from sucrose by esterification with long-chain fatty acids, such as palmitic or stearic. Its structural formula is shown in Figure 5. Because it is a simple ester, which should hydrolyze readily under attack by bacterial action to sucrose and fatty acids, it was predicted that this new product, called Sucrodet, would be biologically "soft." BOD and activated sludge feeding studies conducted by McCarty (2) proved this to be the case.

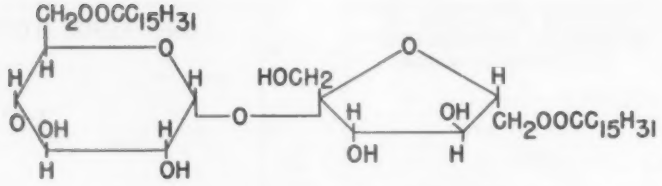

FIGURE 5.—Chemical structure of Sucrodet D-600.

Frothing

A great controversy has developed over the cause of excessive frothing at many activated sludge plants. It has divided those in the profession into three distinct camps—those who are positive that syndets are the cause, those who disclaim syndets as the cause, and those who are utterly confused by the claims and counterclaims made by the first two groups. It has been pointed out many times that there has been a nearly perfect correlation between syndet consumption and degree of frothing, but such an argument appears to be not too convincing.

McCarty (2) conducted a series of tests in a lucite test column 9 ft high and 4 in. in diameter, which add considerable information on the frothing tendency of syndets. His studies were all made using Cambridge, Mass., tap water and commercial grades of surfactants of known purity. Air was supplied at a rate of 0.96 cfm per sq ft of surface area through a small carborundum diffuser located 4 in. above the bottom of the column. Because ABS is the major surfactant used in most syndet formulations and, in addition, is biologically "hard" and apt to carry through treatment processes to exert its effect, it was used as the reference material.

Aeration Rate

A study was made to determine the significance of aeration rate on the degree of frothing produced. A water depth of 50 in. was used in the 9-ft column to allow sufficient freeboard for observations of froth height. Two concentrations of ABS were studied—1 and 1.5 mg/l. The results (Figure 6) show that serious frothing was produced by concentrations of ABS as low as 1 mg/l and at air flow rates as low as 0.5 cfm per sq ft of surface area.

Froth height appeared to be directly related to aeration rate at rates above 0.5 cfm. It may be concluded that aeration rate is a most important factor in frothing problems. Since aeration rates of about 12 cfm per lin ft of tank are common in practice and less than one-half of the tank volume can be considered in the ascending column, it seemed reasonable to choose an aeration rate of about 1 cfm per sq ft of surface area in subsequent studies. A rate of 0.96 cfm was actually used.

Depth Considerations

Although aeration tanks do not vary greatly in depth, a study of the significance of depth and how it might affect frothing tendency was performed. The results (Figure 7) show that depth is a most important consideration. The concentration of ABS needed to produce a given height of froth decreased markedly as water depth increased. The data demonstrate that concentration of ABS is not the important consideration, but rather that the total amount of ABS in the column of water is the major consideration. These data indicate that as little as 0.5 mg/l of ABS in a conventional aeration tank could give rise to as much as 20 in. of froth.

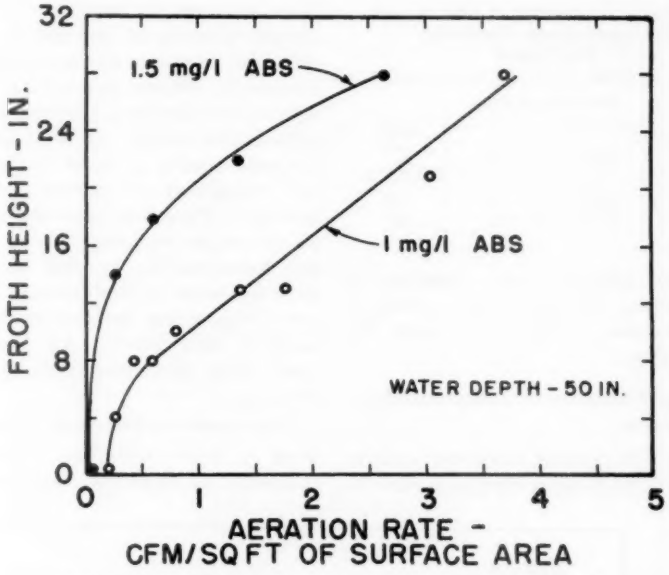

FIGURE 6.—Effect of rate of aeration on frothing of ABS.

Distribution of Syndet in Froth and Liquid Phases

McCarty (2) conducted a study to determine the distribution of surfactant between the froth and liquid phases using two concentrations of ABS: 0.5 mg/l, which gave only 2 in. of froth; and 2.0 mg/l, which gave 25 in. of froth. As shown in Table III, he found that 28 per cent of the ABS had passed into the froth in the former case and 65 per cent in the latter.

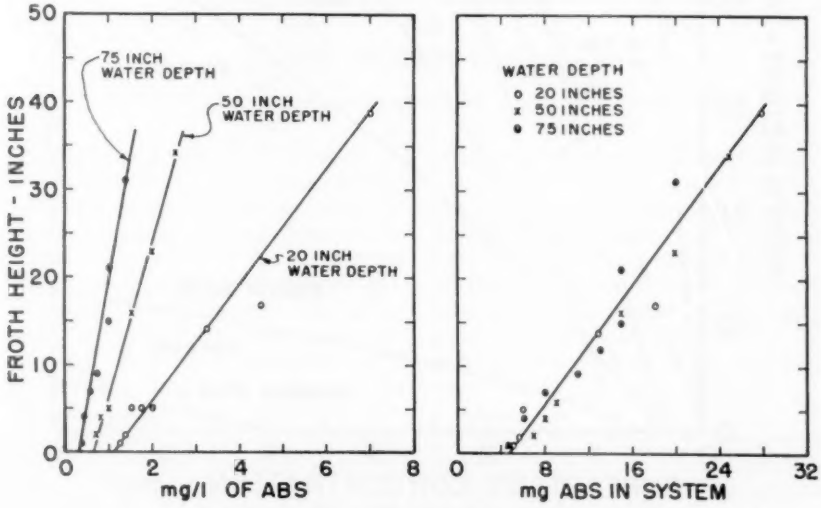

FIGURE 7.—Effect of water depth on frothing of ABS.

TABLE III.—Distribution of ABS in Froth and Liquid Phase (Cambridge Tap Water)

ABS Added (mg/l)	ABS in Liquid Phase		Froth Height (in.)
	(mg/l)	(% remaining)	
0.5	0.36	72	2
2.0	0.70	35	25

Thus, it appears that frothing is nature's way of ejecting an unwanted material from a liquid to speed its purification.

Frothing Character of Individual Surfactants

It is well known that surfactants vary widely in their frothing ability. Some are used in formulations for the specific purpose of increasing sudsing character to please the demands of the housewife. Others are known to have definite low frothing character. Little information exists on the minimum amounts needed to cause frothing under conditions of sewage treatment practice. Therefore, representatives of all the major surfactants used in syndet formulations, as well as others, were subjected to test under the same conditions, using the test column and aeration rate noted. All tests were made using 10 l, or a depth of 50 in., of water.

The results of the study (Figure 8) show a wide variation in frothing character, as expected. Igepon T–77,

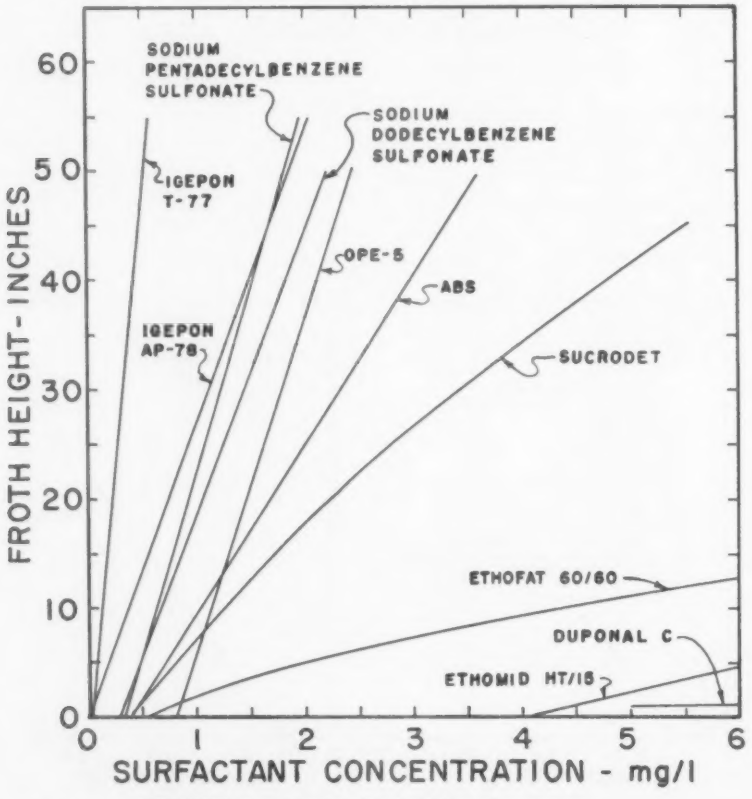

FIGURE 8.—Comparative frothing of surfactants.

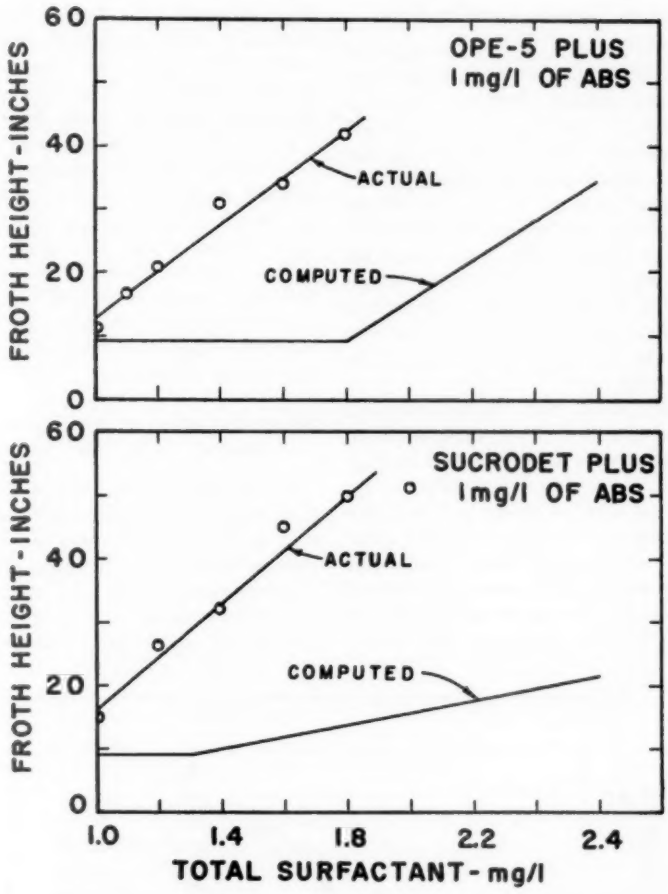

FIGURE 9.—Frothing characteristics of surfactant mixtures.

a sulfonated amide, was found to be the most potent frother. Amides have been used to a considerable extent to increase frothing characteristics of retail formulations. Notable among the group are the three alkyl benzene sulfonate surfactants studied. The pentadecyl and dodecyl benzene sulfonates appeared to produce somewhat more froth with increased concentration than commercial ABS, which is a mixture containing several polymers when the alkyl group is derived from propylene.

It is to be noted that all the ABS-type compounds started producing a noticeable froth at a concentration of about 0.3 mg/l. Ethofat, Ethomid, and Duponal C were found to yield very little froth as compared to the others. The new nonionic, Sucrodet, produced considerable froth, quite comparable to commercial ABS. The polyethylene glycols caused no frothing at levels as great as 50 mg/l.

Among the new "toilet bars," Vel was found to produce significant froth at a concentration of 2 mg/l, but Dove and Zest showed no frothing tendency at 20 mg/l.

Frothing of Syndet Combinations

The studies by Lynch (11) suggested that combinations of surfactants may have much greater frothing character than might be predicted by simple addition effects. An investigation was made of this aspect by studying the frothing character of a wide variety of individual surfactants in combination with ABS. The tests were all made using 10 l of water (50-in. depth) containing 10 mg of ABS. The second surfactant was added to the water in increments and observations made on froth height.

It was found that the behavior of the mixtures fell into three classes. Two classes were as illustrated in Figure 9. One class, represented by OPE–5, an alkyl phenoxy polyethylene glycol, appeared to be completely compatible with ABS and additional frothing was noted as soon as additions were begun. No significant enhancement of frothing tendency was noted. The second class, represented by Sucrodet, was completely compatible with ABS also, but frothing was greatly enhanced as compared to the computed behavior of the combination. The third class, represented by the polyethylene glycols, showed no significant influence, positive or negative, on the frothing tendency of ABS.

A special study was made of how the new syndet "toilet bars" affect the frothing character of ABS. Vel was found to enhance frothing greatly, but both Dove and Zest showed significant depressing effects.

Other Potential Froth-Forming Substances

It has been known for a long time that many industrial wastes are difficult to treat by the activated sludge process because of frothing problems. Notable among these are wastes from the wood-pulping industry, the production of antibiotics, and the meat-

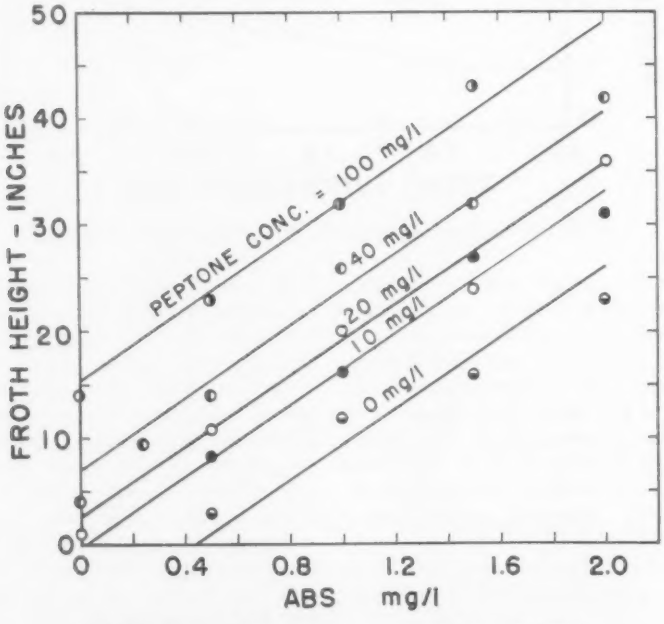

FIGURE 10.—Effect of peptone on frothing of ABS.

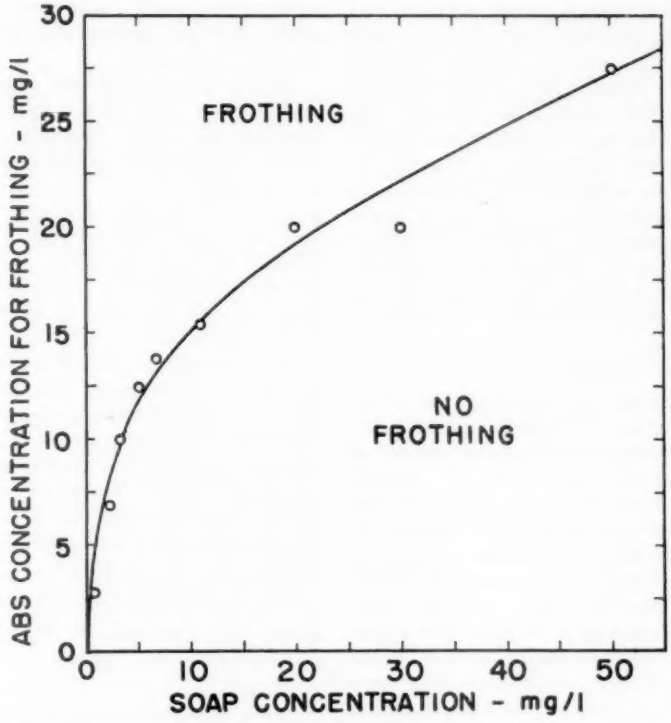

FIGURE 11.—Amount of ABS required to produce frothing at varying soap concentrations.

packing industry. Where these wastes occur in domestic sewage in any appreciable amount, frothing can be expected.

Munro and Yatabe (12) have reported on investigations with synthetic sewage plus added materials, which have indicated that protein degradation products enhance frothing, whereas fat and calcium and magnesium soaps depress frothing. These observations are in agreement with those obtained in the studies reported herein.

McCarty (2) studied the frothing character of peptone in the presence of ABS. His results (Figure 10) show that peptone alone in Cambridge tap water gave a noticeable froth at a concentration of about 15 mg/l and increased to about 15 in. at a concentration of 100 mg/l. In the presence of ABS the effect appeared to be directly additive and without enhancement. Because the amount of protein degradation products which exist in a normal sewage-activated sludge mixture, particularly after 1- or 2-hr aeration, is very small, it is highly questionable as to whether protein degradation products are normally an important consideration.

McCarty (2) made a study of the anti-frothing characteristics of soap. For this investigation he used castile soap at several concentrations in Cambridge tap water and determined the amount of ABS needed to produce frothing. The results (Figure 11) show that ABS requirements are drastically reduced as soap concentration decreases. These data are of particular significance, as they undoubt-

edly illustrate a major reason why frothing problems have become more widespread and intense during the past five years. Soap consumption in the United States has declined materially during this period and syndet sales have increased phenomenally. When one adjusts these values to the growing population, it is easy to argue that aggravated frothing conditions are a result of lowered soap consumption and a much greater ratio of syndets to soap in present day sewage.

Air Requirements

A number of reports in the literature indicate increased air requirements in activated sludge treatment of sewage since the advent of syndets. It has been known for considerable time that oxygenation of sewage by either bubble or surface aeration is considerably slower than in the case of clean water (13)(14). Eckenfelder *et al.* (15) recently presented information on the oxygenation of a number of compounds and industrial wastes which showed considerable hindrance to oxygen transfer.

Lynch investigated the effect of a wide variety of syndets (16) and surfactants on oxygen transfer in Cambridge tap water using bubble aeration. A summary of his findings on the anionic and nonionic surfactants (Figure 12) shows that all had a serious effect. It may be noted that those which interfered to the greatest extent reduced the rate of aeration by more than 50 per cent.

It is recognized that a wide variety of organic substances interfere with the transfer of oxygen into sewage. However, the majority of such substances are destroyed during biological treatment and oxygenation rates should approach that of clean water. In the presence of biologically "hard" surfactants, recovery is not as rapid or as complete; undoubtedly it is this factor that has led to increased air requirements at many treatment

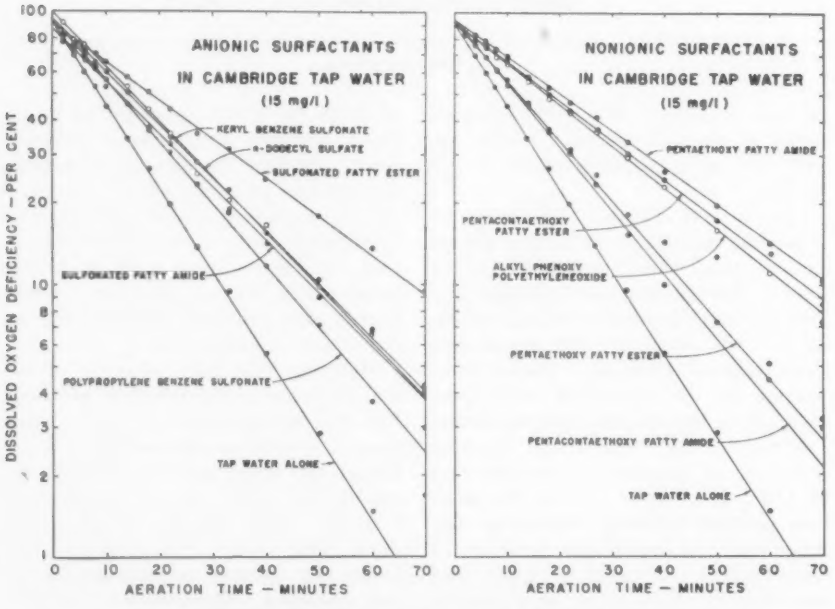

FIGURE 12.—Effect of surfactants on oxygen transfer.

plants. Another factor involved is related to the smothering action of froth, which prevents reaeration from the surface. This has been a serious matter with many mechanical aeration units, which depend to a considerable extent upon surface aeration.

Final Clarifier Operation

Two new problems in final clarifier operation have developed within the past few years. One of these is related to the collection of significant amounts of greasy materials as floating scum. This has been particularly evident in plants operating as high-rate activated sludge units. The difficulty has been attributed to the presence of syndets and improper removal of grease in primary sedimentation units. It should be recognized, however, that concurrent with increased use of syndets there has been increased use of household garbage units and such practice has materially added to the grease content of sewage. Therefore, it is highly questionable as to which factor is the major cause.

The second problem relates to severe froth formation in final effluent channels produced by free fall of the effluent over the weirs. In many plants, where sufficient hydraulic head is available, the effluent is run over a cascade to increase the DO content before discharge to the river. The froth produced in either case leaves a telltale signal on the receiving body of water. The frothing problem in final effluent channels has been overcome in some plants at the expense of reduced aeration, by decreasing the distance of free fall at the effluent weirs, simply by raising the water elevation in the channels.

Efficiency of Treatment

There is considerable difference of opinion as to the effect of syndets on the efficiency of treatment, as expressed in terms of suspended solids or BOD removals. It is reasonable to expect such disagreement, as most treatment plants are designed with capacity sufficient for loads expected 15 to 20 years in the future. In plants that are underloaded, particularly new plants, it is logical that they should be able to accommodate unusual conditions without showing distress. In plants where design capacity has been reached or surpassed, the effects would be more noticeable. In general, it may be said that where biologically "soft" syndets have been involved, no problems have developed; but where biologically "hard" detergents are present in any significant amount, purification has suffered (17)(18).

The extent of nitrification accomplished during sewage treatment is considered by many Europeans as an important criterion of the degree of purification. It is probably the major reason why so many reports from that area refer to syndets as having an adverse effect on the efficiency of treatment. In the United States little attention is paid to this matter and results are based, in general, on BOD and suspended solids removals, both of which are more or less independent of nitrification.

Receiving Streams

The receiving body of water is being considered more and more as part of the treatment process in the United States. Current practice is to design plants in such a manner as to keep plant costs at a minimum and utilize the receiving stream purification capacity to its fullest extent. It becomes pertinent, therefore, to consider the fate of syndets and the effects of their presence on reaeration capacity.

Persistence of Syndets in Receiving Streams

It is to be expected from the information presented that effluents from primary treatment plants, and even those from plants employing secondary treatment, will carry significant

amounts of syndets to the receiving water. To determine how long these materials persist under such conditions, Simpson (19) conducted a series of studies in the laboratory under simulated river conditions. At about the same time Hammerton (20) performed a similar study in England. The results of the two investigators are shown in Figure 13. It will be noted that the information obtained by each was almost identical. Both found the biologically "soft" alkyl sulfate to disappear within one to two days, whereas the biologically "hard" alkyl benzene sulfonates persisted for many days. The keryl benzene sulfonate, which contains an appreciable percentage of straight chain alkyl groups with secondary attachment to the benzene ring, showed considerably less persistence than did the tetrapropylene benzene sulfonate, which has alkyl groups that are highly branched and attached principally at tertiary carbon atoms. These findings are in agreement with the results of Ryckman (10) who found the polypropylene-derived ABS compounds to be essentially inert to biological attack.

Reaeration

Will the surfactants which persist in receiving waters have a serious effect on the rate of reaeration and, therefore, on purification capacity? Reist (21) studied the effect of several surfactants at a concentration of 5 mg/l

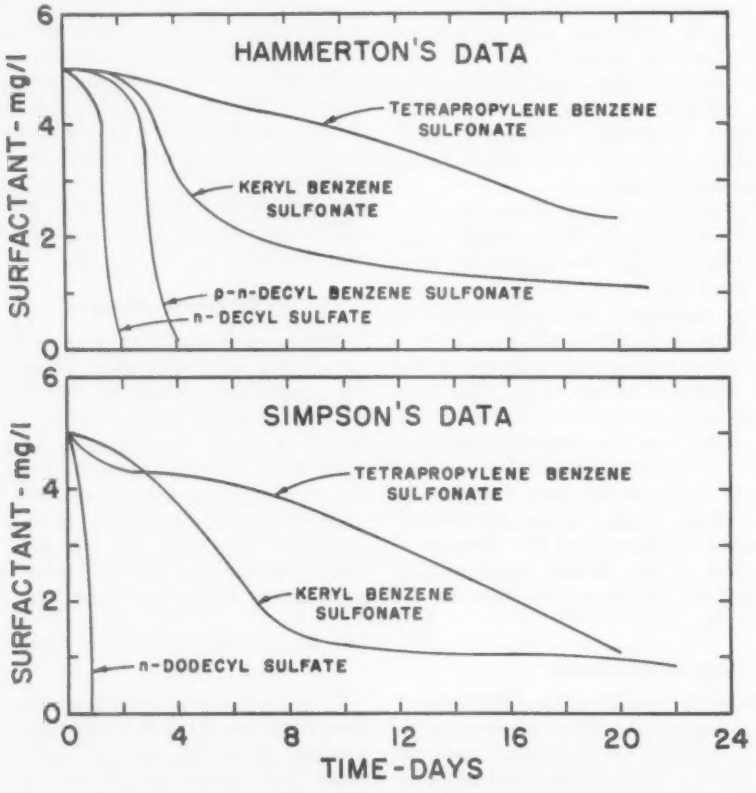

FIGURE 13.—Destruction of surfactants in river water.

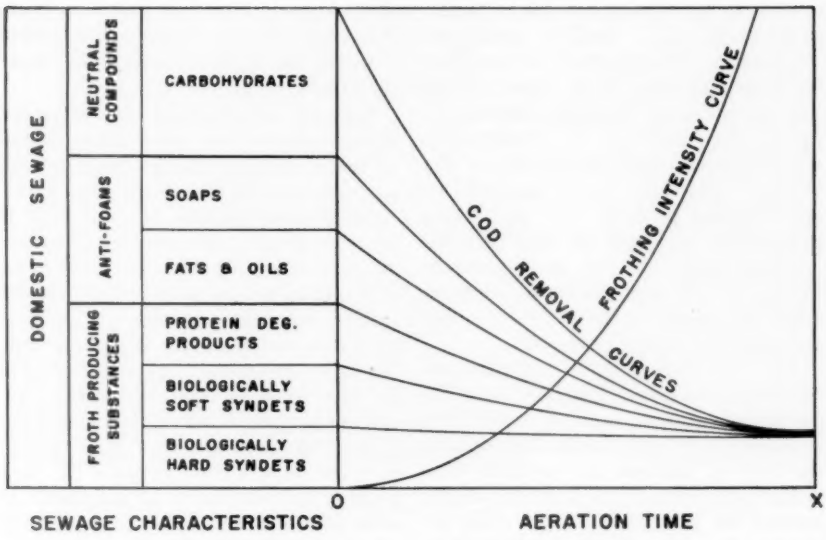

FIGURE 14.—Character of domestic sewage and relation of frothing character during activated sludge treatment to biological assimilability.

under static and turbulent flow conditions. He found, as did Kehr (14) in working with sewage, no significant effect under static conditions, but a considerable decrease under conditions of turbulent flow. From these results it may be concluded that residual surfactants will have little, if any, effect on reaeration rates in lakes and the effect will vary in flowing streams, increasing in magnitude as the degree of turbulence increases.

Discussion

Over the course of the past decade, there has been a strong tendency to place the blame for many of the ills of sewage treatment processing upon the presence of syndets. Because of the wide variety of surfactants used in formulating the retail products, it seemed unfair to make a blanket condemnation of all. On the other hand, it did not appear reasonable to attempt exoneration of all by results obtained on a few retail products of unrevealed composition.

The results obtained by Bogan (9), Ryckman (10), and McCarty (2) have done much to "fingerprint" the chemical and physical behavior of the various surfactants under conditions of activated sludge treatment. This information has provided a base for a reasonable explanation of the frothing problem, about which so much controversy has raged. This study attempts to piece this new information together with known information on the biological stabilization of normal sewage components.

A composite interpretation of why frothing is not a problem in aeration of sewage, but becomes gradually worse as aeration of activated sludge mixtures progresses, is shown in Figure 14. According to this concept, sewage consists of three major types of materials—anti-foams, froth-producing substances, and neutral substances. In raw or settled sewage the anti-foaming substances are normally present in sufficient amounts to prevent frothing. As biological degradation of the sewage occurs, all components of the

sewage except the biologically "hard" surfactants are readily stabilized. Thus, as the concentration of the anti-foaming materials is decreased, frothing develops in intensity dependent upon the amount of biologically "hard" surfactants contained in the sewage. Basically, the magnitude of the frothing problem will be related to the rate at which the anti-foaming materials are destroyed, the concentration of residual surfactants such as ABS, the depth of the aeration tanks, and the rate of air application.

In general, it may be said that all surfactants decrease the rate at which oxygen transfer occurs from the gaseous phase to the liquid phase. In the case of diffused air aeration this would seem contrary to what one might predict on the basis that lowering of the surface tension should allow smaller bubbles to be formed and, therefore, a greater surface area exposure per unit volume of air supplied. As a rule, much smaller air bubbles are formed initially, but the effect of the increased surface area is offset by two major factors that cancel any benefits to be derived therefrom and, in fact, greatly reduce efficiency of oxygen transfer. These two factors are (a) a marked tendency for the small air bubbles to coalesce into large bubbles with greatly reduced surface area and (b) concentration of the surfactants and anti-foams at the interface. The latter is probably the major consideration and some concept of its magnitude can be estimated from the composition of froth, which is essentially a collection of interfaces segregated from the liquid. Donaldson (22) has reported that froth collected from aeration tanks in New York City, after condensing to a liquid, contained 7,700 ppm total solids, 1,800 ppm grease, and 900 ppm of alcohol-soluble detergent. Munro *et al.* (23) reported a concentration of 5,100 ppm of syndets in collapsed froth. In view of the high concentrations of syndets and other organic materials found in froth, it is reasonable to conclude that oxygen transfer is impeded mainly by these materials.

Control of frothing in activated sludge plants has been accomplished in many cases by maintaining a high aeration solids concentration. Although such practice was of help it has not proven adequate in many instances, nor capable of controlling frothing in recent years as the syndet concentration has increased. The case of Cranston, R. I., is a notable one. In 1952, Anderson (24) reported that he was able to control frothing by maintaining aeration solids above 2,000 ppm. By 1956 frothing had become so severe at Cranston (Figure 15) that a spray system had to be installed. It does not seem reasonable to expect the adsorptive ability of activated sludge to keep pace with the increased concentration of syndets in sewage. Therefore, it is to be expected that more and more plants will be forced into installing froth control facilities. In this connection, it should be mentioned that forcing the surfactants to remain in the sewage will probably increase air requirements, because the sewage cannot free itself of the materials which interfere with oxygen transfer. In addition, where anti-foaming substances are added, oxygen transfer will be further reduced because of their presence. Lynch (16) found that a wide variety of anti-foams affected oxygen transfer seriously.

The Future

It is reasonable to assume that syndets are here to stay and their popularity, though not necessarily so, is apt to increase. It becomes the responsibility of those in the business of sewage treatment to focus attention on untoward effects which such materials produce and call the attention of the manufacturers to the problems. But the claims must be positive and the

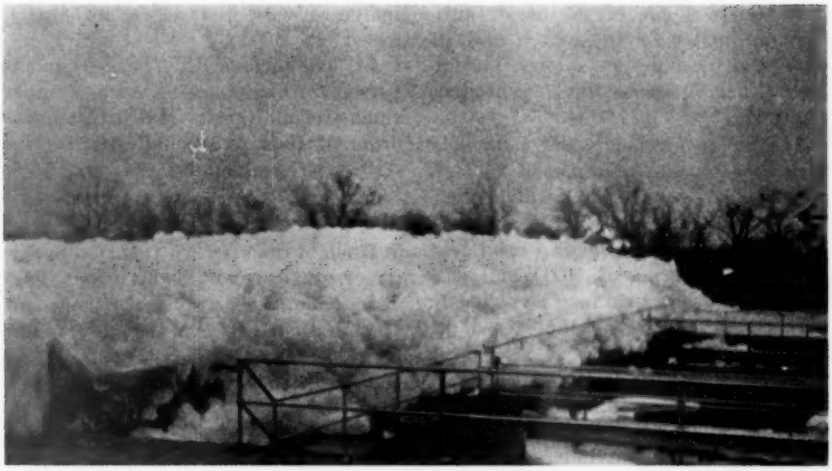

FIGURE 15.—Frothing of aeration tanks at Cranston, R. I., is an example of the inability of increased aeration solids to cope with increased frothing tendency.

pitfalls of blanket statements must be avoided. With a basis of mutual trust, it would seem reasonable that manufacturers of syndets will attempt to modify their products so as to minimize problems related thereto. On the basis of present knowledge, it appears reasonable to urge producers of syndets to substitute biologically "soft" surfactants for biologically "hard" materials as much as possible and to initiate research to discover new and perhaps better biologically "soft" surfactants which can compete with ABS.

Conclusions

From these studies the following conclusions are drawn:

1. Suspended solids removal by primary settling tanks is not measurably affected by syndets at present concentrations or concentrations to be expected in the future.

2. Grease removal by primary settling units is affected to a slight extent in a negative manner.

3. Syndet removal by primary settling units will decrease precentagewise as syndet consumption increases, and will level off at less than 10 per cent.

4. Syndet which accumulates in sewage sludge drawn from primary settling units may be approaching toxic levels.

5. All alkyl sulfates and esters and amides, regardless of the nature of their hydrophilic group, are biologically "soft" and cause no serious problems in sewage treatment.

6. Alkyl benzene sulfonates, alkyl phenoxy polyethylene glycols, and polyethylene glycols are biologically "hard" and escape in significant amounts in the effluents of biological treatment plants.

7. Alkyl benzene sulfonates and alkyl phenoxy polyethylene glycols are principally responsible for frothing problems at activated sludge plants.

8. The current syndet toilet bars (Dove, Vel, and Zest) consist of biologically "soft" materials and do not cause problems in sewage purification.

9. The problem of frothing at activated sludge plants is related to the presence of certain surfactants. The intensity of frothing is a function of aeration rate, depth of aeration tanks, concentration of surfactants, and concentration of anti-foam materials.

10. Soap is one of the major antifoaming materials in sewage and its biological destruction allows biologically "hard" surfactants to produce frothing.

11. Air requirements are materially increased by the presence of biologically "hard" surfactants, which interfere with oxygen transfer.

12. Efficiency of biological treatment processes in terms of BOD and suspended solids removal may be seriously reduced as plants reach or exceed design capacity.

13. Syndets have no significant effect on reaeration rates in static bodies of water such as lakes, but do interfere with oxygen transfer under conditions of turbulent flow. The interference increases with the degree of turbulence.

14. The biologically "hard" syndets persist for many days in streams under summer conditions. Half-lives in the order of 15 days are indicated for the ABS-type compounds.

Acknowledgments

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31ST ANNUAL MEETING AT DETROIT, OCTOBER 6–9, 1958

The 31st Annual Meeting of the Federation of Sewage and Industrial Wastes Associations, to be held October 6–9, 1958, at the Sheraton-Cadillac Hotel, Detroit, Michigan, in conjunction with the annual meeting of the Michigan Sewage and Industrial Wastes Association, is shaping up well. One of the really outstanding technical programs of the entire series is in store for those who plan to attend.

Typical of the excellent coverage to be offered are the following:

1. Symposium on cost reduction of sewage treatment design, construction, and operation.
2. Sewer maintenance panel discussion (a similar one offered at the Los Angeles Meeting in 1956 was enthusiastically received).
3. Industrial wastes forum.
4. Research symposium.
5. Symposium on industry-municipality cooperation.
6. Operators' forum.

Under the sponsorship of the Water and Sewage Works Manufacturers Association, there will be a full and varied exhibit, conveniently located, of equipment, products, and process developments in the sewage and industrial wastes field.

Those who attend are promised a varied and interesting program which will be well worth the effort. A record attendance is expected, so begin to make your plans NOW!

Watch the JOURNAL for further announcements in July.

OXIDATION OF RADIOACTIVE GLUCOSE BY AERATED SLUDGE

By Nandor Porges, Aaron E. Wasserman, William J. Hopkins, and Lenore Jasewicz

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Treatment of organic waste by aerated sludge depends on the metabolic activities of many microorganisms present in the mixed liquor. Although aerated sludge is a melange of many types of microorganisms (1) in which all possible pathways of carbohydrate metabolism could occur to complicate the picture, studies on the biochemical oxidation of dairy wastes (2) show that complete oxidation of milk sugar involves such distinct activities as (a) removal of soluble material from solution, (b) intracellular storage, (c) oxidative conversion of stored material, and (d) endogenous respiration of cellular components.

Intensive studies in recent years show that carbohydrate dissimilation by bacteria is a complex procedure and may involve more than one metabolic pathway, yet this information has not been applied to the degradation of organic wastes by sludge organisms. Investigations were started to follow gross distribution of a substrate utilized by sludge organisms. Radioactive glucose, labeled at the carbon-1 (C-1) or carbon-6 (C-6) atoms, was used to follow the fate of the glucose molecule with respect to CO_2 evolution and sludge formation.

These studies appear to be the first of this nature in the fields of sanitation and industrial wastes. Radioactive tracers have been used in measuring sewage flow times and in procuring other operational data. Rorschach and Reid (3) designed a laboratory-scale pilot plant to study effects of radiophosphorus on biological sewage oxidation. In 1954 Grune and Eliassen (4) investigated effects of P^{32} on microbial life to establish tolerance levels for amounts of radioactivity to be allowed in sewers and sewage treatment plants. Skrinde and Sawyer (5) applied Warburg techniques to the safe and economical determination of radiophosphorus effects on the BOD of domestic sewage. One C^{14} study applicable to the investigation has been mentioned in a recent note. Dawes and Holmes (6) noticed that *Sarcina lutea* build up a non-polysaccharide reserve within the cells which, when later metabolized, seemed to suppress oxidation of exogenous substances.

The results obtained in these preliminary experiments, although incomplete, indicate that the glucose molecule is degraded, and the component carbon atoms are used at various rates and enter into various reactions.

Methods

Sludge

Propagation of an active aerated sludge commenced two weeks before studies were initiated. A sludge culture containing 5,000 ppm cells was built up in the Humfeld fermentor by daily feedings of 20 g dried skim solids to 20 l of culture. Temperature was maintained at 30° C, aeration was continuous and in excess. The sludge was settled, washed twice with distilled

water, then adjusted to a concentration of 2,500 ppm COD, which was considered equal to 2,000 ppm sludge solids (7). This served as seed for the Warburg studies. Seed for the later studies in sintered glass aerators was prepared in a like manner.

Warburg Respirometer

Manometric studies were carried out by the "direct" method of determining O_2 and CO_2 (8). Double side-arm flasks were used, a set of two for each time interval sample. In one side-arm was placed 0.5 ml of sludge containing 1 mg cell solids. The second side-arm contained 0.2 ml 2N H_2SO_4. The reaction chamber of each flask contained 0.5 ml of 0.05M phosphate buffer (pH 6.7), 0.1 ml $(NH_4)_2SO_4$ containing 10μg N, 0.1 ml glucose-1-C^{14} (12,000 cpm), and 0.8 ml water. One flask of each pair received 0.2 ml 20 per cent CO_2-free NaOH in the center well immediately prior to adjusting the manometer.

After 10-min equilibration in the bath at 30° C, the sludge cells were tipped from the side-arm into the main chamber of each flask and measurements in gas changes were begun. The acid in the second side-arm of each pair of flasks was tipped into the main chamber at 0, 0.5, 1, 4, and 5.5 hr to stop the cell activity and to liberate bound CO_2.

The flask containing NaOH in the center well of each pair was used for the determination of radioactivity. The NaOH was carefully removed and the center well was rinsed several times with CO_2-free NaOH. The rinsings were combined with the NaOH and treated with 5 ml 2M NH_4Cl and 10 ml 0.5M $BaCl_2$. The precipitated $BaCO_3$ was collected on filter paper with the aid of a precipitation apparatus.

The 2.2-ml acid-treated cell suspension was transferred from the main chamber of the flask to a centrifuge tube and the cells were separated. The Warburg flask was washed with 1.8 ml CO_2-free water and the cells were resuspended in this wash and centrifuged again. The supernatant and the wash water were combined and an aliquot taken for combustion by the persulfate wet combustion method of Calvin *et al.* (9). The total quantity of the separated cells was decomposed by the same method. The liberated CO_2 was trapped in N NaOH, precipitated as $BaCO_3$, and collected. The radioactive material was counted and the values corrected to infinite thinness.

Sintered Glass Aerator.

The second series of experiments was conducted in an apparatus previously described for measuring CO_2 evolution (10). Each aerator held 200 ml of mixed liquor consisting of 25 ml 0.5M K_2HPO_4, 25 ml 0.5M KH_2PO_4, 5 ml 0.1 per cent $(NH_4)_2SO_4$, 100 mg sludge in 100 ml, and 45 ml containing 45 mg glucose-6-C^{14} (1,200,000 cpm). The sludge was added after purging the mixed liquor with CO_2-free air. Aeration was continued by passing CO_2-free air through the sintered glass sparger at the rate of 200 ml per minute.

The spent air was passed through measured amounts of 0.03 N NaOH to capture the evolved CO_2. The use of NaOH avoided clogging of the glass dispersion tubes, as often occurred with $Ba(OH)_2$. Also, uniform dispersion of the CO_2 was required for accurate sampling and assaying of radioactivity. The two receiving tubes of each set contained sufficient amounts of the standard NaOH as predetermined by a trial run using plain glucose. These tubes were prepared under nitrogen gas.

At the indicated sampling times, the NaOH tubes were removed and replaced with another prepared set. The NaOH, now containing CO_2, was transferred quantitatively to 100-ml flasks under nitrogen gas and made up to volume with CO_2-free water. A 10-ml aliquot was transferred to a 50-ml flask for the volumetric determination of CO_2 by treating with neutral $BaCl_2$·-

$2H_2O$. After standing for 4 hr or longer (11), an aliquot of the supernatant was titrated with 0.01 N HCl, and the carbon content of the original samples was determined.

Four aerators containing glucose-6-C^{14} were prepared, permitting the removal of an aerator at 0, 5, 24, and 48 hr. Samplings at 0.5, 1, and 3 hr were made from the one aerator removed at 5 hr. Two ml of the aerated mixture were added to 0.2 ml 2N H_2SO_4 in a centrifuge tube and treated as previously described in the Warburg respirometer studies. A 25-ml sample was also removed, placed in a tube containing 0.04 ml conc H_2SO_4, and an aliquot taken for the determination of total COD (12). Supernatant COD and reducing sugar (13) were determined after filtering 10 ml through asbestos. (Reducing sugar was also run in the Warburg experiment.) At 0, 5, 24, and 48 hr the sludge was inactivated with 0.3 ml conc H_2SO_4; aeration, except for the primary sample, was continued for 10 min. CO_2-free water was added to replace water losses prior to assaying. In addition, one aerator was run 48 hr without glucose in order to obtain endogenous evolution of CO_2. A water blank was also prepared. This experiment was conducted at room temperature.

The manometric experiment with glucose-1-C^{14} was completed in 5.5 hr and gave information on the distribution of the radioactive C^{14}-1 between the cells, CO_2, and supernatant solution. The second experiment conducted in sintered glass aerators gave like information concerning C^{14}-6. Aeration was continued over a period of 48 hr in the latter experiment, giving an opportunity to follow sludge oxidation and other changes, since there was sufficient material for analyses.

Distribution changes in radioactivity are reported on the basis of the total count at the initiation of each experiment (12,200 for the 0.45 mg glucose-1-C^{14} used in the Warburg flasks, and 1.2 million for the 45 mg glucose-6-C^{14} in the aerators).

Results and Discussion

Marked differences were observed in the rate of utilization and distribution of the two labeled carbon atoms of the glucose substrates. Direct comparisons were made of the results obtained from the manometric and aerator experiments because prior studies on dilute substrates showed results to be comparable.

Supernatant

Glucose, measured by the routine reducing value determination, apparently disappears from the supernatant solution very rapidly (Figure 1). In 1 hr approximately 75 per cent is utilized, and by 4 hr less than 5 per cent remains. However, measurement

TABLE I.—Distribution of Radioactivity in Mixed Sludge Liquor Containing 500 PPM Sludge and 225 PPM Glucose (Glucose-1-C^{14} Used in Respirometers and Glucose-6-C^{14} in Aerators)

Aeration Period (hr)	Radioactivity (%)		
	Sludge	CO_2	Supernatant
(*a*) Warburg Study: 1 Mg Sludge Plus 0.45 Mg Glucose-1-C^{14}, 12,200 cpm			
0	1.1	0	98.9
0.5	4.0	2.5	97.1
1	11.2	6.5	87.2
4	27.6*	42.0	16.4
5.5	21.3*	37.3	22.9
(*b*) Aerator Study: 100 Mg Sludge Plus 45 Mg Glucose-6-C^{14}, 1.2 Million cpm			
0	0.7	0	99.3
0.5	26.0	0.9	70.2
1	11.8	1.7	57.5
3	23.7	3.0	62.7
5	38.8	4.5	40.3
24	26.0	26.6	37.4
48	24.0	45.7	29.0

* Low, should probably be about 40.

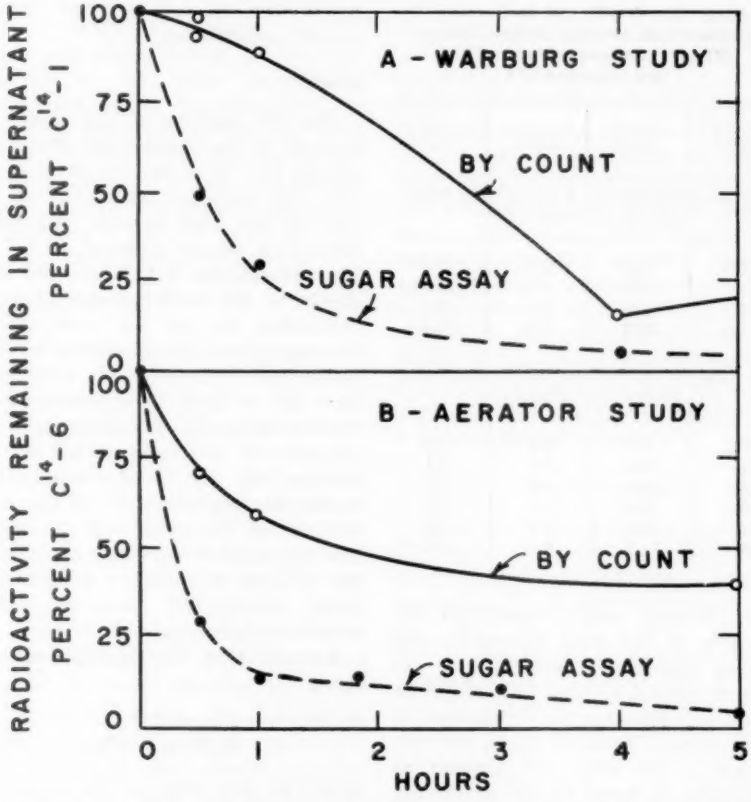

FIGURE 1.—Glucose reduction from supernatant solution in (a) Warburg study and (b) aerator study.

of the radioactive carbon moieties contributed by the glucose indicates that considerable carbonaceous material remains in solution and that the various carbon atoms of glucose are utilized at different rates and to different extents. Table I and Figure 1 show that C-6 is initially removed from solution more rapidly than C-1; in 1 hr 43 per cent of the C-6 activity disappeared, as compared to only 13 per cent of C-1. After 5 hr, however, the sludge removed 80 per cent of C-1 and as much as 60 per cent of C-6 (at a time when tests of reducing values indicated 95 per cent of the glucose had disappeared). Further aeration of the sludge for 48 hr resulted in the slow removal of an additional 11 per cent of the C-6 from the supernatant.

Carbon Dioxide

Column 3 in Table I shows the proportion of the total radioactivity evolved as CO_2. The breakdown of C-1 occurred more rapidly than that of C-6. In 4 hr 42 per cent of C-1 appeared as CO_2, whereas in 5 hr only 4.5 per cent of C-6 was released in the gas. Only after 48 hr of incubation did the sludge evolve 45.7 per cent of the C-6 as CO_2.

The total CO_2 evolution, 42 per cent of the weight of C in glucose, approximates the previously reported values for the breakdown of lactose by sludge

TABLE II.—CO_2-C and Radioactive C Evolved from Aerating Sludge-Glucose Mixture Containing Glucose-1-C^{14} and Glucose-6-C^{14}

Aeration Period (hr)	CO_2-C (ppm)	Labeled C (ppm)	Labeled C (%)
(*a*) Warburg Study: 1 Mg Sludge Plus 0.45 Mg Glucose-1-C^{14}			
0.5	3.2	0.4	12.5
1	6.7	1.0	14.9
4	35.6	6.3	17.7
5.5	38.6	5.6	14.5
(*b*) Aerator Study: 100 Mg Sludge Plus 45 Mg Glucose-6-C^{14}			
0.5	8.7	0.2	2.3
1	14.2	0.3	2.1
3	20.4	0.5	2.5
5	28.3	0.7	2.5
24	50.6	4.0	7.9
48	71.7	6.8	9.5

(14). Because each C represents 16.7 per cent of the total glucose-C, and because only one C was labeled, the ratio of labeled to total CO_2 might be of value in assessing the breakdown of the C atoms. Table II shows the percentage of the total CO_2 present as radioactive C, based on the conversion of the data to ppm. If each C atom of glucose was equally converted to CO_2, $C^{14}O_2$ would be equal to 16.7 per cent of the total CO_2 formed. This value was approached, as determined by the labeled activity of C-1. However, that fraction of C-6 present in the CO_2 at the end of 5 hr was only 2.5 per cent of C^{14} present originally in glucose.

It would appear, therefore, that because C-6 was not dissimilated to CO_2, the C atoms were not equally utilized and the other carbons, -2, -3, -4, or -5 must contribute more than C-1 to the total CO_2 evolved and, therefore, were oxidized more rapidly and to a greater extent than C-1 or C-6. Similarly, such differences in the utilization of C was obtained with *Serratia marcescens* by Wasserman and Hopkins in work as yet unpublished.

Sludge

The C^{14} content of the sludge increased as the experiment progressed (Table I). However, the greatest uptake was observed with C-6; 26 per cent of the total activity was transformed to sludge material in 0.5 hr. The assimilation of C-1 occurred more slowly in the earlier stages of sugar utilization, but by the conclusion of the experiment the maximum incorporation had occurred. (It is believed that the 4- and 5.5-hr radioactivity determinations for the sludge utilizing glucose-1-C^{14} are too low, and by calculation of the total radioactivity should be approximately 40 per cent. Because of the nature of the sludge and the manner in which it grew, it was difficult to obtain a proper sampling, particularly from the manometric experiment.)

According to the equation of synthesis,

$$8(CH_2O) + 3O_2 + NH_3 \rightarrow C_5H_7NO_2 + 3CO_2 + 6H_2O,$$

about 60 per cent of the soluble C added to sludge mixture should be assimilated into new cell material or stored as readily utilizable reserve material (14). Determinations made at the end of 5 hr indicated that only about 40 per cent of the labeled carbon was assimilated. With further incubation, appreciably more C-1 could not be stored because so little still remained in the supernatant. However, with C-6 assimilation may have continued beyond 5 hr with degradation occurring in the latter portion of the 24-hr period.

The uneven distribution of the labeled C atoms of glucose in the CO_2 evolved, the sludge, and the residue remaining in solution (aside from irregularities in determination), point up the fact that glucose, or any other substrate, is not used as an entity by

the microorganisms in the sludge. The various metabolic patterns of the sludge population result in the degradation of the sugar into smaller components, which are then used for energy or synthesis at varying rates. Further studies with glucose labeled in the remaining C atoms, and identification of the metabolic products, should allow a complete picture of the degradation of glucose by sludge.

Changes in COD

The aeration experiment gave the opportunity to follow the changes in COD over a period of time. The total amount of starting COD was 625 ppm for the sludge and 240 ppm for the added sugar, making a total of 865 ppm. Table III shows that the actual analysis of the total COD at the start was 851 ppm, of which 274 ppm were soluble COD; apparently, solubles were present with the sludge. In 0.5 hr 167 ppm of glucose had disappeared, yet the total soluble COD decreased only by 27 ppm, whereas the solids gained only 37 ppm. In this experiment the maximum sludge solids were reached in 5 hr, with almost complete removal of glucose and considerable removal of total soluble solids.

If 766 ppm are considered as the maximum sludge solids COD reached in 5 hr, there was a loss of 15 per cent by the 24th hour and 39 per cent by the 48th hour. This may be compared to the 23 per cent loss of endogenous respiration at 48 hr, when 577 ppm sludge solids COD was reduced to 444 ppm. The greater change in the fed sludge must be attributed to assimilated material more easily oxidized and utilized by the multiple population. The significant amount of oxygen-demanding soluble material was apparent. Although the results are somewhat erratic, due doubtless to sampling difficulties, the general trends are apparent. The radioactivity of the sludge solids followed the sludge solids COD, reaching the maximum in 5 hr and then declining.

TABLE III.—Changes in COD of Components in a Buffered Sludge-Glucose Mixture Aerated 48 Hours

Aeration Period (hr)	Chemical Oxygen Demand (ppm)			
	Total Solids	Soluble Solids	Sludge Solids	Glucose
0	851	274	577	240
0.5	851	247	604	73
1	818	235	583	35
3	803	155	648	31
5	862	96	766	14
24	767	114	653	—
48	599	127	472	—
Endo	508	64	444	—

Observations

These experiments were purely exploratory. It is hoped to repeat this study and include glucose containing labeled carbon in each position and the universally labeled carbons. In that way, more information would be obtainable as to whether or not the mixture of sludge microorganisms utilizes glucose in the same manner as selected pure cultures. Studies of this type may give some insight as to the source of residual soluble oxygen-demanding substances that are always present in aeration processes.

It was observed that C-1 and C-6 of the glucose were incorporated into cellular material at different rates and to varying degrees. A substantial amount of the radioactivity remained in the supernatant solution and was used slowly, if at all, and was associated with the residual COD.

Sugar removal, as measured by reducing power, was practically complete within 4 hr, although the actual rate of removal was different in each experiment. Radioactivity of the solution was high, even after such glucose removal. The C^{14}-1 remaining was about equal to the amount that should have been removed during assimila-

tion. The C^{14}-6 remaining was much greater and at the expense of this carbon in the CO_2.

It appears that C-1 was more readily available for energy purposes than C-6, because in 5 hr about 37 per cent of the C-1 was found in the CO_2, as compared to 4.5 per cent of the C-6. The latter carbon does become slowly available over long periods of aeration. It required 48 hr to remove as much C-6 as was removed in 5.5 hr of C-1.

Because neither C-1 nor C-6 is completely removed from solution, they are probably integral parts of conversion products of the glucose, which may have been acted upon outside of the cell, or waste products excreted from the sludge cell. These probably contribute to the residual COD found in the aeration process. Additional studies, using both radioactive and chemical techniques, are indicated.

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Set Aside October 6–9
for the
Federation Meeting in Detroit

Industrial Wastes

FLOTATION TREATMENT OF SEWAGE AND INDUSTRIAL WASTES*

By E. Sherman Chase

Partner, Metcalf & Eddy, Boston, Mass.

It has become nearly general practice to consider the solids carried by sewage and other liquid wastes as existing in two states. Sewage, for example, carries solids which may be divided into four categories; namely, floating, readily settleable, finely divided, incapable of settling except over long periods of time, and dissolved.

Conventional treatment of sewage and industrial wastes involves essentially two procedures dealing with its constituent solids: first, the separation of the solids capable of removal by physical means; second, the oxidation of organic solids in solution. With the exception of the removal of coarser solids by screens, the method most commonly used for the removal of undissolved solids has been sedimentation.

Much has been written on the design of sedimentation facilities and many mathematical formulas have been proposed to explain the phenomenon of sedimentation. It would seem that some of the hypothetical discussions of sedimentation are based largely on the assumption that the particles involved are discrete. Unfortunately, in the case of sewage at least, this assumption is erroneous because of the very nature of the solids themselves. Some of the solids are discrete, but many of them are of a semi-flocculent nature. Many of them are of a specific gravity very close to that of water, others have a specific gravity greater than water.

If sedimentation tanks had to deal only with discrete particles, or with particles heavier than water, they could be designed on the basis of the theoretical formulas previously referred to. In recognition of the variable characteristics of solids in sewage and in other types of wastes, and to take into account the nondiscrete nature of much of the suspended matter and its low specific gravity, flotation methods have been developed.

Flotation as a treatment process has been in use slightly more than 50 years. During the first half of this period it was used exclusively in the mining industry for the concentration of metallic ores. During the late 1920's the Scandinavian paper industry developed a flotation process for the recovery of paper fibers from paper mill wastes. The equipment used was called "savealls." In more recent years flotation has been applied to the treatment of other types of wastes even where the recovery of worthwhile by-products is not involved. Such applications of the process have been for the purpose of reducing stream pollution.

Review

Inasmuch as most of the examples of flotation experience in the fields of wastes treatment are those of the past

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few years, it may be desirable to review briefly its development to the present state.

The first patent covering the flotation process was issued in 1903 for the separation of sulfide-bearing ores from valueless nonmetallic materials. About 90 per cent of nonferrous materials now mined, excluding aluminum, are being concentrated by flotation.

As used in the mining industry and in some wastes treatment facilities, the process can be called "froth flotation." In this type of flotation air is admitted either under pressure through diffusers or by mechanical means in a manner similar to the action of an egg beater. The size and dispersion of the air bubbles depend on the volume of air introduced and on the speed of the agitating device.

In the case of the mining industry, chemical conditioning agents are added to the ore slurry to facilitate the inclusion of the metallic concentrates with the froth and to permit the useless materials to settle. The froth containing the metallic concentrates is skimmed from the surface of the flotation unit preparatory to further processing. In the case of wastes treatment, chemical conditioning may or may not be required.

The "savealls" of the paper industry operated under quite different conditions from those encountered in the mining industry (Figure 1). With paper mill wastes, air is dissolved in the white water prior to its admission to the "saveall." This air is either educted on the suction side of the feed pump or admitted to the discharge side of the pump under pressure. The white water containing air dissolved at pressures from 30 to 60 psi is then passed through a short-period closed retention tank to permit the release, through an air relief valve, of such undissolved air bubbles as may be present.

Following this retention tank the wastes, from which the dissolved air, still under pressure, has not had opportunity to escape, are admitted to the flotation tank through a control valve. As the wastes enter the flotation tank the pressure drops and the dissolved air is released, just as the bubbles of carbon dioxide are released when a bottle of ginger ale is uncorked. As the fine bubbles are intercepted by suspended particles of solid matter, they act as air lifts or buoys that bring them to the surface, the mixture of bubbles and solid particles producing foam or froth. In the case of the paper industry, this froth consists largely of paper fibers.

Chemicals for improving floc formation can be added before or after the pump, after the retention tank, or at the point of admission of the wastes

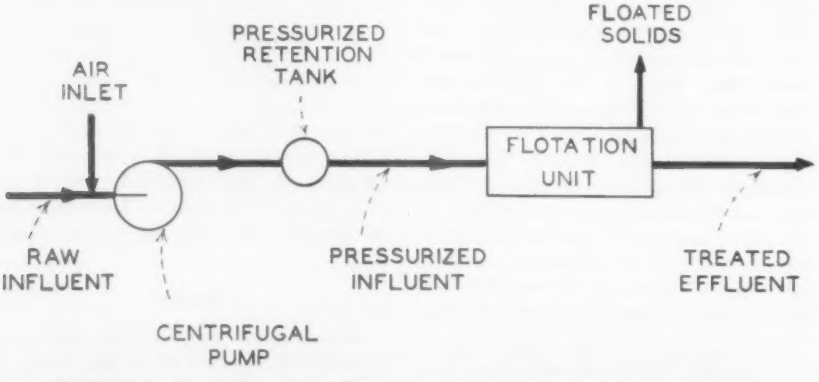

FIGURE 1.—Flow diagram of flotation system using complete pressurization.

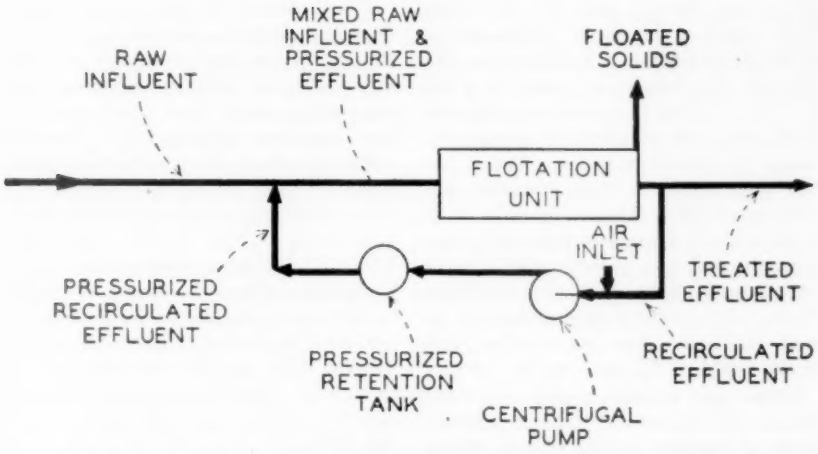

FIGURE 2.—Flow diagram of flotation system using effluent pressurization and recirculation.

to the flotation tank. Coagulation and the formation of floc is an extremely important part of nearly all flotation processes. Consequently, it must be emphasized that preliminary laboratory and pilot plant studies must be made prior to the adoption and design of any flotation treatment facility in order that methods of coagulation and flocculation may be of the greatest effectiveness.

Inasmuch as many wastes, including sewage, contain organic material already in flocculent form, or in the process of flocculating, certain proprietary flotation units currently available make provision for such inherent flocculation (Figure 2). Because existing flocs may be broken up by pumping, this type of unit introduces the air dissolved in clarified effluent rather than in the raw wastes. In this case the raw wastes are introduced to the unit by gravity. This method of introducing the air avoids the breaking up of flocs present in the raw wastes as the wastes pass through the pump and is particularly important where floc formation is difficult but necessary for effective clarification.

A further modification occurs where the unit operates under vacuum and the air present under normal atmospheric pressure is released in a closed system. With this type of unit, air is diffused into the wastes in an open channel, after which the wastes are discharged into an enclosed vacuum tank. In this tank the dissolved air is released under negative pressure and the resulting bubbles bring the solids in suspension to the surface in a manner similar to that occurring in the previously described types of flotation.

Applications in the Sewage and Wastes Treatment Fields

Sewage Treatment

Application of the flotation principle in the treatment of sewage has developed largely since 1942. At present there are but few plants of substantial size at which there have been more than a few years of experience (1)(2).

Apparently the earliest use of flotation in the field of sewage treatment occurred in California, where the installation of flotation units has been on a relatively small scale. One plant (3) treating 1.0 mgd of domestic sewage has a flotation unit of the dissolved air type. This unit is reported to have removed 55 per cent of the suspended

solids and 70 per cent of the 5-day BOD when used as an alternate to plain sedimentation. Information (4) relative to a treatment plant in Utah less than 1 year in operation indicates a 38 per cent removal of suspended solids by flotation units. There are two such units 40 ft in diameter, accompanied by a thickening unit 12 ft in diameter, for concentrating the scum from the flotation units combined with humus tank sludge following trickling filters. The plant treats a flow of 10 mgd, which involves an overflow rate in the units of 2.7 gpm/sq ft.

There are sewage plants in California (5)(6) which receive periodic loads of canning wastes and at which vacuum-type flotation units are provided to remove hulls and skins. Such removals prevent scum formation on subsequent primary sedimentation tanks. There is some evidence that the flotation units remove about 40 per cent of suspended solids at overflow rates of about 2 gpm/sq ft of tank area and 10- to 20-min detention. The concentrated scum had a dry solids content of 4½ to 5 per cent by weight. Due to the short detention periods, reductions in BOD appear to have been only about 10 per cent.

Hay (7) gives the results of exhaustive experiments at Racine, Wis., in 1954. A flotation pilot plant with a capacity of 25 gpm was operated for eight months on sewage. The results indicated that consistent removals of 56 to 65 per cent of suspended solids were possible. The unit provided a 20-min detention; the results with this short detention period compared favorably with removals in conventional settling tanks having 2 hr or more settling time.

At present, there are a number of other locations where consideration is being given to installation of flotation units instead of primary sedimentation tanks (8). Flotation units under consideration include all the types referred to previously.

Clarification of the mixed liquor from the aeration units in the activated sludge process has presented, at times at least, rather difficult problems. One pilot plant study from which information has been obtained (9) involved a flotation unit at an activated sludge plant treating industrial wastes. This pilot plant operated at a rate of 25 gpm with mixed liquor containing 1,100 to 1,700 ppm of suspended solids. Flotation reduced the suspended solids to 120 ppm, equivalent to a 90 to 93 per cent reduction. This was accomplished with detention times from 15 to 35 min. The floating scum removed had 2 to 3 per cent of solids on the dry basis.

A significant factor involved in the flotation of activated sludge lies in the fact that sludge removed by flotation is likely to be high in dissolved oxygen, which tends to prevent septicity of returned sludge.

Sludge Concentration

At present considerable attention is being given to methods for concentrating raw sludge prior to discharge to digestion tanks. So-called "thickeners" of the gravity type with mechanical plows for concentration of the deposited solids have been utilized in several of the more recently installed sewage treatment plants. However, in some quarters attention is turning to the substitution of flotation units in place of gravity-type concentration tanks (10). This is true at Chicago, where flotation investigations have involved a reasonably large pilot plant.

Two full-scale sludge concentration units involving the flotation principle have been operating a short time in Utah (4) and Ohio (11). Experience at these two installations is so short that data of any definite significance are not available. There are some indications (10)(12), however, that with raw primary sludges concentrations of 6 to 7 per cent solids may be obtained in about 30 min. Limited experience

with the concentration of activated or mixed sludges indicates that concentrations of 3 per cent solids can be obtained readily or that further concentrations of 6 per cent solids can be procured by drainage. At the Utah installation (4) mixed raw sludge and humus tank sludge have been concentrated to about 5 per cent or more solids.

Flotation by utilization of gas produced by anaerobic digestion of sludge is to be adopted at the new Allegheny County plant in Pennsylvania (13). The gas produced in the raw sludge during its partial digestion in open tanks will provide the buoyancy for lifting the bulk of the sludge solids, thus concentrating the sludge prior to incineration.

Industrial Wastes

Utilization of the flotation process in the treatment of industrial wastes varies according to the type of waste being treated. It is of interest, however, to cite three major categories in which a considerable number of installations have been successful; namely, those related to oil, paper, and food processing.

Industrial Wastes—Oils, Grease, and Fats

An oil refinery in Califonia has one of the largest industrial wastes flotation installations about which information is available (14). This installation treats up to 5.8 mgd and includes two 35-ft diameter flotation units, following primary sedimentation tanks. The oil content of the raw wastes is reduced from 7,000 or 8,000 ppm to about 100 to 125 ppm by primary sedimentation. After treatment in the flotation units the residual oil in the effluent approximates 30 to 45 ppm, which is below the state limit of 75 ppm. These units operate at overflow rates of 2 gpm/sq ft. Due to the necessity for control of air pollution in the vicinity, both the clarifiers and flotation tanks are covered. Reported operating costs, including depreciation allowance, are $60 per million gallons.

At another oil refinery in California (15) where shallow well water supplies must be recharged by the return of waste waters, these waste waters are chemically treated and given some form of filtration followed by flotation using compressed natural gas to provide the buoyancy for lifting the oil particles remaining in the filtered water. This filtered water coming to the flotation unit contains 500 ppm of oil, which is reduced to about 18 to 35 ppm by the flotation unit. Natural gas at 45 psi is injected into the waters treated by the flotation process.

Miscellaneous oil- and grease-containing wastes, such as those from machine shops (16) (17) (18) (19), airplane (20) (21), and railroad car-washing (22) facilities, have been treated with apparently satisfactory results by flotation units. Naturally, the results vary with the character of the wastes. Nevertheless, most of the installations for which data are available appear capable of removing 90 per cent of the oils, grease, and suspended solids, and in some cases removals as high as 97 per cent have been obtained.

Flotation units have been successful for more than 10 years (23) in the treatment of wastes from the manufacture of soaps and edible oils. An installation in California is described as consisting of four flotation units with a combined capacity of 6,500 gpm. This installation is reported (24) to have removed up to 94 to 96 per cent of suspended solids and 99 per cent of fats and oils, leaving a residual of the latter of about 40 ppm.

Removal of grease and associated soils contained in laundering wastes resulted in additional benefits besides those of pollution abatement (25). Flotation treatment of these wastes resulted in a clarity of the treated efflu-

ent equal to that of tap water. This made possible the reuse of the water in further laundering operations. Potential savings in the order of 85 per cent of the water consumption and 70 per cent of the heating requirements for the hot water could thus be realized.

Some years ago wool scouring wastes containing a high percentage of greases and lanolins were treated in a pilot flotation plant (26). Prior to flotation the wastes were first cracked with calcium chloride. The unit was not well adapted to treating the type of wastes produced at the wool scouring plant in question and considerable difficulty was experienced with its operation. However, when satisfactory operation could be secured approximately 97 per cent of the fats and suspended solids were removed, as well as about 80 per cent of the BOD. The heterogeneous nature of the solids in the waste indicated the need for pretreatment prior to flotation.

Industrial Wastes—Paper Processing

Although "savealls" were developed by the paper industry as an economic necessity for the recovery of the paper fibers, these units have had a concurrent beneficial effect in the reduction of stream pollution. Because "saveall" operation is now basically a part of the paper-making process, relatively little data are now available as to their accomplishments apart from the overall paper-making operation. A published report (27) relative to the installation of a flotation unit at a mill producing tissue paper gives results obtained by the unit. Although the wastes from the mill contained extremely fine fibers, 96 per cent of the suspended solids were recovered by flotation, the effluent containing only 30 ppm of suspended solids. The unit was operated with an overflow rate of 2½ gpm/sq ft and a detention time of only 20 min.

Another published report (28) relates to an installation at a board mill in Michigan. Here a 1,000-gpm flotation unit reduced paper fiber losses to 0.054 per cent of production, this achievement being considerably better than that required by the state (1 per cent). Prior to installation of the unit, the wastes carried into the receiving watercourse about 2,900 lb of suspended solids per day; after the installation, the suspended solids load was reduced to about 78 lb per day. At the same time the BOD discharged was reduced from about 1,000 lb to 275 lb per day.

Deinking of suspensions of waste paper to permit the reuse of the deinked pulp has been a significantly important application of the froth-flotation method (29). Such flotation is able to concentrate the ink and dirt particles in the froth, leaving behind paper stock suitable for reuse after bleaching.

Industrial Wastes—Food Processing

The food preparation and canning industry has applied flotation to the treatment of its wastes for a number of years. However, limited data are available with respect to the results obtained with the types of wastes from this industry. In addition to those municipal installations where flotation has been employed to handle sewage receiving at times large quantities of food processing wastes (5)(6), there are a number of instances where the food processing industry has used flotation directly for treatment of its own wastes.

An account (11) of the treatment by flotation of a slaughterhouse waste containing 4,360 ppm of grease, 6,270 ppm of suspended solids, and 3,250 ppm of BOD states that the 500-gpm flotation unit gave reductions of these constituents of 96, 93, and 54 per cent, respectively.

A 200-gpm flotation unit treating waste from a small meat packing plant

has been under direct observation for some time (30). The wastes at this plant contain from 100 to 400 ppm of grease, 400 to 750 ppm of suspended solids, and 1,400 to 1,700 ppm of BOD. Under optimum operating conditions the unit has produced reductions of 93, 80, and 77 per cent, respectively, of these constituents.

Industrial Wastes—Miscellaneous

There are reports of successful treatment by flotation of various other types of wastes. Among such wastes are naphthalene-containing wastes from by-product coke plants (31), and wastes carrying finely-divided carbon from various gas and coke chemical industries.

Experience

A review of the literature relating to flotation and direct experience therewith demonstrates clearly the importance of carrying out detailed and exhaustive pilot plant studies on the particular type of wastes for which the flotation process is under consideration. Experience has shown that there are types of wastes which cannot be successfully treated by flotation.

The problems related to the coagulation, flocculation, and flotation of industrial wastes are far more complicated than those involved in water purification. Water coagulation and flocculation include, of course, types of chemicals, pH, floc formation, and settling characteristics of the floc. All these variables are involved in the treatment by flotation of industrial wastes. In addition, there are involved the order and point of application of chemicals, if required; the method employed for the application of air; and the ratio of recycled effluent to raw wastes, especially in the concentration of sludges. Furthermore, it must be determined whether or not nonfloatable materials require provision for their removal independently of the froth produced by flotation. In determining the details of a flotation unit design, the characteristics peculiar to the particular wastes involved must be carefully studied. Even where basic flotation equipment is applicable, there are likely to be modifications required to meet the variable characteristics of the wastes in question.

Economics

Two major economic factors must be considered when evaluating flotation processes in sewage and industrial wastes treatment. These factors are initial construction costs and operating costs.

The initial construction costs are related to the available space and its utilization. When applicable, flotation with an average detention time of about 20 min and overflow rates of 2 gpm/sq ft requires approximately one-sixth of the total area of sedimentation tanks to provide the same degree of removals. Sedimentation tanks are almost always of concrete and are constructed on the site. Flotation units can be made of sheet metal in fabricating shops and shipped as units directly to plant sites, where they can be erected with a minimum of delay. Considerable savings in cost of construction and installation may be realized, although each case should be considered on its own merits.

The operating costs of flotation units include the relatively expensive item of power for pumping. This cost factor may in some cases limit the usefulness of the process to the smaller treatment plants, but not necessarily so. However, even in the industrial wastes field, where operating costs are relatively unimportant as compared with construction costs and space considerations, there are only a few really large installations. In cases where the flotation process produces more concentrated sludges as compared with plain sedimentation, smaller but more efficient sludge pumps may be required.

Where settled solids must be removed from the flotation units, the small areas from which such solids are removed involve much less submerged scraping equipment than is the case with sedimentation units.

Where chemicals for flocculation are required, the cost of chemicals may be slightly higher than for conventional coagulation and sedimentation. This is partly due to the shorter time available for floc formation, necessitating somewhat larger dosages.

Conclusion

It seems likely that the flotation process will receive more consideration in the future than it has in the past. To what extent it will prove applicable in the treatment of sewage is somewhat problematical. It seems more likely, however, that its application will be in the field of industrial wastes treatment where many of the wastes are relatively uniform in character and where the applicability of flotation can be determined with reasonable accuracy by means of pilot plant studies prior to the design of a full-size plant or the selection of any specific equipment.

It is advisable, therefore, to again point out the necessity for thorough investigation before the adoption of any type of flotation, particularly as to the limits of tolerance of the basic data of design. Inadequately designed units are likely to result in far less satisfactory results than in the case of sedimentation tanks, because in the flotation units detention periods of only 20 min or so are involved, as compared with 2- or 3-hr detention in the case of sedimentation units.

Acknowledgments

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JOINT ASCE MANUALS NEAR PUBLICATION

As a result of authorization given at the Boston Federation Board Meetings in October 1957, and action anticipated by the ASCE Board of Direction, two joint manuals, which have been under preparation for several years by committees of the two organizations, are reaching the final editorial stage.

The first manual, "The Design and Construction of Storm and Sanitary Sewers," has been prepared under the leadership of a joint committee headed by Mr. Bernal H. Swab, Consulting Engineer of Syracuse, N. Y. The manual will offer the results of comprehensive efforts to present detailed information to assist those interested in the design and construction of sewers.

The second manual, "Sewage Treatment Plant Design," has been written by a joint committee headed by Dr. Daniel A. Okun, Professor of Sanitary Engineering, University of North Carolina, Chapel Hill, N. C. This manual will offer the user a thorough and usable compilation of data and information on plant design practices.

Each of these manuals will be available from both organizations, paper bound, with a 6- by 9-in. manual format. Those sold by ASCE will have the standard blue cover of ASCE manuals, while those sold by the Federation will have the orange cover to match the color of previous Federation Manuals of Practice. Each manual will approximate 300 printed pages. Prices of the manuals will be the same from both organizations. Availability and prices of these manuals will be announced as early as possible in THIS JOURNAL.

ELECTRICAL MANUFACTURING PLANT WASTE PROBLEMS*

By F. Horrocks

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The Schenectady, N. Y., works of the General Electric Company has had many changes, both in its products and its facilities. In 1887 Thomas Edison took over a group of buildings intended as a locomotive factory and started the Edison Machine Works. By 1892 he had greatly expanded the plant; two dozen new buildings had been added, total employment included nearly 800 people, and it had become a part of the Edison General Electric Company. In the same year that company was merged with the Thompson-Houston Company of Lynn, Mass., and became for the first time the General Electric Company.

By the end of the 1930's employment at Schenectady had reached 25,000. During the war it reached a peak well over 40,000, but is now around 31,000.

The Schenectady works produces primarily the larger size rotating equipment—steam turbine generators, vertical generators for water turbine drives, and various types of motors. In addition, electronic tube, chemical vehicle, and paint manufacture is carried on at the plant. There are also extensive development engineering and manufacturing laboratories.

Figure 1 is an aerial view of the Schenectady works, which consists of 270 building structures with a floor area of approximately 9,000,000 sq ft on a 700-acre site adjacent to the Mohawk River. The plant ground level is about 12 ft above normal river level.

From 1940 through 1955 the floor area was increased 33 per cent and the use of water nearly 100 per cent. This rapid growth subjected the plant service facilities to a severe strain and generally used up any marginal capacities that existed.

This had been especially true with the water supply and sewer systems. As a result, a 5.8 million dollar extended program of modernization to bring these services in line with the needs of the works is now under way. This program is about two-thirds complete.

General

The untreated water used for manufacturing purposes and fire protection is pumped from the Mohawk River and distributed through a 90-psi piping network. The total installed pump capacity for this service is 52,000 gpm. About 28 mgd are pumped from the river for plant use. The plant also contains a new 120,000-gpm low-pressure water system for stream turbine testing and as a partial factory water supply.

Some 1.7 million dollars have been spent modernizing the water supply facilities.

Water for drinking and some industrial purposes is purchased from the City of Schenectady. This averages about 3 mgd.

The plant has two separate sewer systems—the sanitary sewer system and the process and storm water system. The sanitary wastes are discharged into the municipal system to be conveyed through the city treatment facilities. The process wastes and

* Presented at 1958 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 23, 1958.

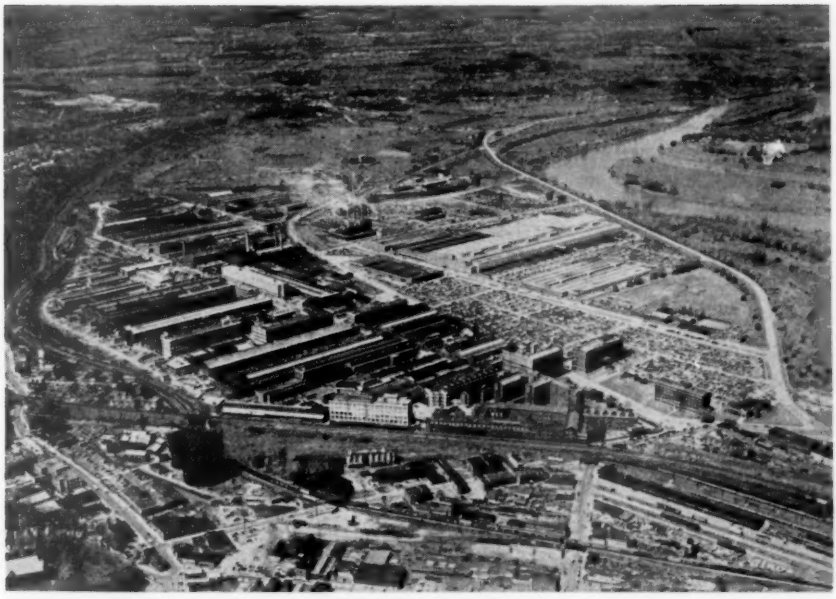

FIGURE 1.—Aerial view of Schenectady works, General Electric Company.

storm water are discharged into the Mohawk River.

The problem of storm water runoff and process water disposition has always been more than ordinarily difficult because of the location of the works in a low-elevation drainage basin where no free-flowing channels can be exploited to drain off surface water and factory wastes. Prior to 1927 little attention was given to this problem; as the works grew, sewers were added as needed. By 1927 the problem of inadequate sewers had become so acute that a major effort was required to provide adequate facilities.

A circular oil skimming pool was provided to keep spent oil out of the river. About the same time pumping facilities of 20,000-gpm capacity with a 48-in. diameter trunk main was installed to convey the plant discharge to the river. A 15,000-gpm storm water pumphouse built in 1914 was not disturbed. This briefly covers the plant sewer system in operation until late in 1956. It was inadequate during heavy rainfalls, with resulting flooding of buildings, streets, and pipe tunnels.

In 1950 a firm of consulting engineers was retained to study the storm and process water problems and develop a long-range program, including the design of necessary facilities to correct the situation.

Survey Activities

As a result of survey efforts carried out by the consulting engineers and plant personnel, specific design information was developed.

Process Waste Flow

Flow measurement data were taken on process water uses and composited. The average daily flow rate for the five days observed was 14,760 gpm. The flow during the 8:00 AM to 4:00 PM shift for the same period averaged 15,000 gpm, or 23 mgd.

For design purposes, taking future growth into account, a flow rate of 33 mgd was decided upon.

Storm Water Flow

The volume of storm water flow had to be established. The area under consideration was 350 acres. Inasmuch as all this is built-up flat ground with the prospect of all roadways being paved and parking areas oiled and stoned, a 100 per cent impervious factor was used in calculations. Based on the foregoing, the curve for runoff from a storm of 5-year average expected frequency, and full development of plant areas, it was recommended that the main and sub-trunk sewers to the treatment plant and pumping station be designed for a capacity of 453 mgd. This total is broken down into 33 mgd for process waste flow and 420 mgd for storm flow. Of this amount it was determined that if pumping capacity were installed for 285 mgd and storage in the system amounted to 320,000 cu ft, the expected flows could be handled satisfactorily.

It was apparent that it was impractical to construct a plant for process water condition that would also accommodate storm flows of this magnitude. It was necessary, therefore, to provide an overflow by-pass around the oil separating facilities to permit by-passing of storm water in excess of design capacity of the oil separators. The increased dilution resulting from the storm flows in the plant system and the river itself was believed to be such that no offense will be occasioned by this by-passing during storms.

Effluent Quality

From the information available it was generally felt that chemical treatment of the effluent was not necessary. However, it was decided that a testing program should be carried out. To evaluate the magnitude of the plant waste problem, samples were collected for a three-week period from the main sewer above and below the connections to the existing oil skimming pool. These were composited for each 8-hr shift.

Table I gives the average waste analyses. It can be seen that the metallic ions in these wastes were not of sufficient concentration to be of concern; for instance, copper content is less than 0.4 ppm and cyanide less than 0.1 ppm. The average oil concentration over the sampling period under consideration fell in a satisfactory range for both the effluent and influent.

The Sewer System

A network of trunk and sub-trunk drains varying in size from 12-in. tile to 48-in. concrete pipe served as the works sewer system. It was, of course, necessary to make detailed analyses of the actual flows and capacities of this system. The system was definitely overloaded, with surcharging in the main 48-in. trunk line to a depth of 4 to 6 ft and a depth of 11 ft in some of the sub-trunks. During storms, innumerable manholes ran full to ground level and in many cases water ran out of the manholes due to head created from roof conductors.

Several different plans were developed for trunk and sub-trunk relief. The final selection, shown in Figure 2, provides for the following:

1. A new main box culvert trunk (7- by 10-ft section) from River Road along West Avenue and paralleling the existing 48-in. trunk in West Avenue.
2. New sub-trunks ranging in size from 24- to 84-in. diameter approxi-

TABLE I.—Average Process Waste Analyses, Former Skimming Pool

Determination	River Water	Influent	Effluent
Susp. matter (ppm)	—	86.6	73.6
Settl. solids (ml/l)	—	0.09	0.06
Copper (ppm)	—	0.35	0.35
Iron (ppm)	—	3.2	2.6
Cyanide (ppm)	—	0.05	0.05
P.E. sol. grease (ppm)	—	8.0	6.5
pH	7.4	7.4	7.3
Oxygen consumed (ppm)	—	67.1	56.8
Diss. oxygen (ppm)	12.3	—	—
Alkalinity (ppm)	73.1	—	—

mately paralleling or, where necessary, replacing the existing sub-trunks.

It is further apparent from Figure 2 that the renovation program has been broken down into stages. Stage 1 has now been completed for about 18 months. It as anticipated that Stage 2 will be started during 1958. The entire project is tentatively planned for completion by 1961.

As shown in Table II, in modernizing the sewer system both the trunk and sub-trunks will be considerably expanded in size. The main trunk line was increased from a 48-in. reinforced concrete pipe to a 7- by 10-ft box culvert. Also, the storm water pumping capacity has been increased from 12,000 to 200,000 gpm.

In constructing the main culvert along West Avenue, the excavation averaged 26 ft below ground level. Well pointing was required, as extensive dewatering had to be done to lower the water table, which was only 8 ft below ground level. This culvert, which extended 1,800 ft, has a slope averaging 3 in. per 100 ft. The heavily reinforced side walls are 12 in. thick, and bottom and roof are 18 in. thick.

The cost of the trunk sewer portion of the first stage was $850,000.

TABLE II.—Sewer System Renovation Program

Item	Size or Capacity	
	Prior to Program	Present Program
Main trunks	48-in. pipe	Box culvert 7 by 10 ft
Sub-trunks	18-30-in. pipe	48-84-in. pipe
Process water pumps	20,000 gpm	25,000 gpm
Storm pumps	12,000 gpm	200,000 gpm

Cost of program:	
1st stage	$2,000,000
2nd stage	950,000
3rd stage	750,000
4th stage	400,000
Total	$4,100,000

FIGURE 2.—Diagram of sewerage program, showing location of pumphouse, oil separators, main trunk, and sub-trunks for the three stages.

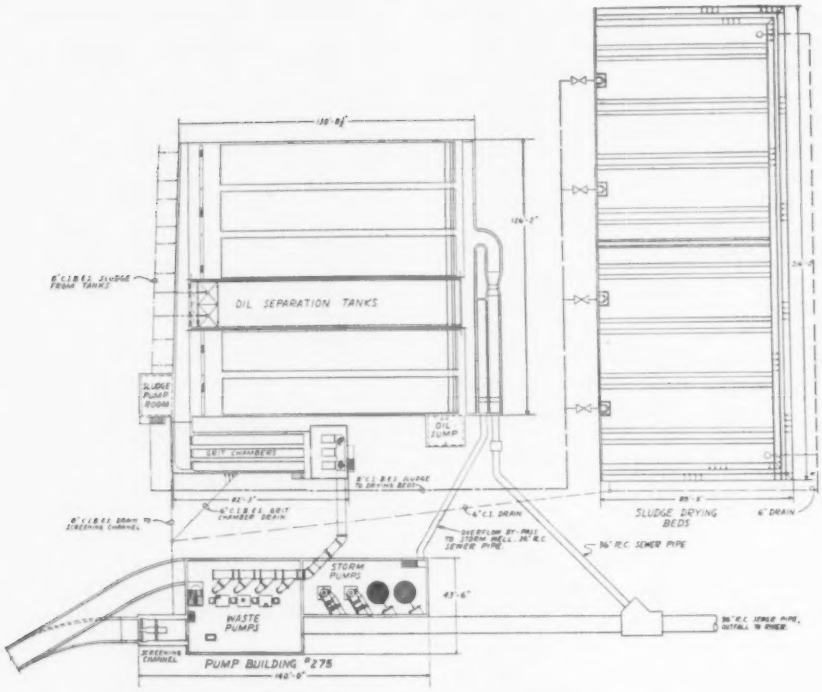

FIGURE 3.—Plan of pump building and oil separator system.

The laterals around and adjacent to buildings are in need of corrective measures, outlined as the fourth stage of the project. This will be accomplished in the field, after operation of facilities provided in the first three stages indicates whether the installation of parallel lines or the replacement of the original lines is the more desirable.

Pump Building and Oil Separators

The unconditioned process waste effluent from the Schenectady works will meet all the criteria for the Class B classification as adopted by the State of New York for this portion of the Mohawk River, except that occasionally a slug of oil might momentarily exceed the oil concentration limits.

The treatment problem, therefore, resolved itself into (a) the removal of oils and greases by flotation and (b) the handling of associated solids deposited by settling. The oil and grease removal was by far the most important and the design, therefore, gave prime consideration to this factor.

An oil separator based on the American Petroleum Institute plans was designed and built. The detailed specifications were developed by the engineers after a comparison was made with other types of separators. It is estimated that the oil separators with equipment cost about $175,000.

Because pumping facilities are necessary for both the storm and process water, it appeared desirable to install these adjacent to the oil separator required to remove oil from the wastes. Figure 3 shows how these facilities have been combined into a single installation.

The trunk sewer connects to the process waste section through an en-

trance chamber of two channels. Flow to each channel is regulated by a sluice gate, which controls and limits the flow to the process wastes wet well during storm periods. A bar screen in each of these channels automatically removes coarse trash. The four process water pumps each have a capacity of 8,333 gpm. Two of the pumps are driven by 2-speed and two by single-speed motors for the purpose of programming from a wet well float level control.

Discharge from the pumps enters a coarse grit removal system consisting of three flow channels designed for a velocity to allow settlement. Chain-mounted scrapers and buckets elevate the grit to overhead storage bins, from which it is discharged by means of a screw conveyor.

From the coarse grit separation channels the water enters six oil separation tanks, each 126 ft long by 20 ft wide and 8 ft deep. Chain drive collectors move the surface oil to the effluent end of the tanks and sludge deposited on the bottom to a sludge sump at the influent end. Separated oil is removed from the tanks with pipe skimmers and collected in an oil collection tank.

Sludge from the tanks is pumped to draining beds. Clarified effluent from the oil separation tanks is measured through a Parshall flume, then flows by gravity through a double tide-gate chamber into a 96-in. line, which also carries the water from the storm pumps, for disposal into the Mohawk River.

The two 40,000-gpm storm water pumps are shown in Figure 4. These start up automatically from a float-programmed control. As stated previously, water only enters the storm water wet well if the flow is in excess of the capacity of the process water pumps. This is controlled by the sluice gates. The oil separators, grit collecting building, and pump building are shown in Figure 5.

For cost reasons the plans were modified at final installation. Initial plans call for four 40,000-gpm storm water pumps to be installed in the

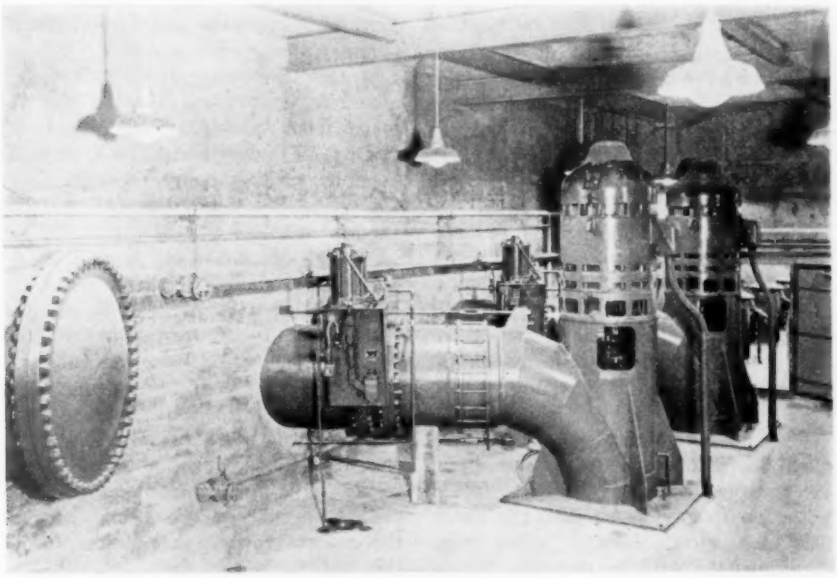

FIGURE 4.—Storm water pumps, with connection for a future pump at left.

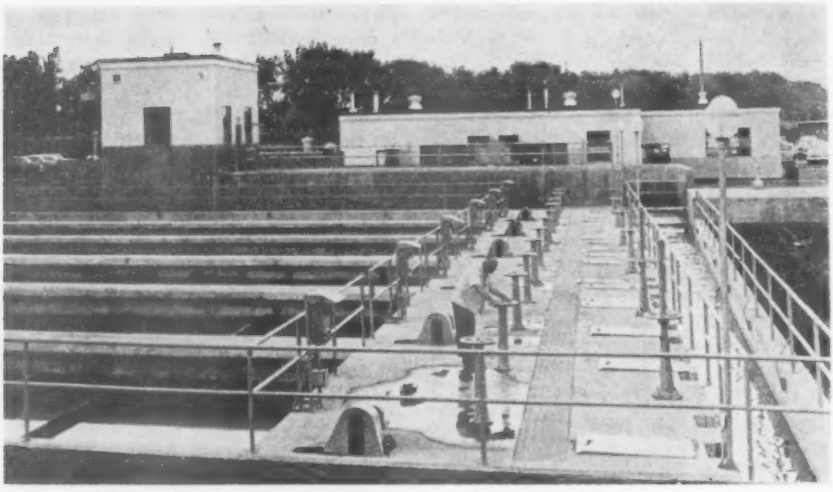

FIGURE 5.—Oil separators, with grit and pump buildings in background.

first installation with space for two more; one pump was to serve as a spare. When built, two 40,000-gpm pumps were installed, with space for two 60,000-gpm pumps to be installed as the final sewers are put into service.

Operation

The pumphouse and oil separator facilities have been in operation about 18 months. The usual preliminary operation troubles occurred, mostly of minor mechanical nature.

A short time after starting up it was discovered that sand had filled the suction well to a depth of 2 to 6 ft. The increased velocity in the old sewer system as a result of the lower elevation of the new main trunks caused a cleaning action on any partly filled sewers. The sand thus cleaned out of the sewers accumulated in the suction well.

The most trouble was encountered with the grit separator channels and its equipment. The conveyor would not pick up any grit unless the water was shut off. Various baffles were experimented with to stop the turbulence and evenly distribute the water between the three channels to stop the washing of the sand out of the buckets. A directional vane at the entrance plus a plate baffle in front of the chain corrected this condition so that sand could be picked up without shutting down.

The next condition encountered was grit carrying over into the influent channel of the oil separators. To correct this, the water level in the grit channels was raised, slowing the velocity from approximately 1 fps to ½ fps. This helped some. At present, as much grit is being removed from the oil tank influent channel as from the grit removal channels.

The sludge beds did not work as anticipated. After the sand bed drain field became covered with solids, the water would not seep through the sludge layer. Because the sludge is nearly 100 per cent impervious, as it became deeper the water ran over the bed retaining walls. In the final solution it was recognized that the water would have to be drained from the surface; a variable-elevation drain at the remote corners has accomplished this very satisfactorily.

The pumphouse and treatment fa-

cility are attended by one operator per shift around the clock, seven days a week. Extra help is provided as needed in the daytime. The annual operating cost for 1957 of the oil separators and pumphouse alone, excluding taxes, rental, and depreciation, was $62,000, approximately one-half being maintenance and one-half operating costs. It is expected that maintenance cost will decrease in the future. The cost for power was $19,000.

In 1956 the Control Departments moved the last of their operation out of the Schenectady works and this considerably reduced the oil and metal-finishing wastes being discharged into plant sewers. An additional reduction in oil discharge has resulted from the repairing of underground leaks and the reduced use of fuel oil from the conversion of ovens and furnaces to gas fuel.

Several checks since the separator has been in operation indicate that the effluent oil content is less than 3 ppm.

Summary

The rainy weather flooding problem at the Schenectady works was serious. Completion and operation of the first stage of the program to renovate the sewer system leads to the conclusion that when finished the improved system will be completely adequate to correct the flooding problem.

Comprehensive surveys of the effluent from the Schenectady works have demonstrated that the metal-finishing operations being carried out there do not add waste products in sufficient concentration to be objectionable in the Mohawk River. When the plant effluent discharged through the former oil skimming pool it was possible for a spill of oil in the plant to impart an objectionable oil slick to the Mohawk River. Operation of the new oil separator and comprehensive analyses of the effluent which it yields, indicate that the oil load to the river is now well below that which could cause trouble.

Acknowledgment

Acknowledgment is expressed for the aid and counsel of Kenneth S. Watson, Consultant, Water Management and Waste Control, General Electric Company, in the development of this paper.

CLASSIFICATION OF FIRE EXTINGUISHERS

A broader classification method has been developed for portable fire extinguishers which, according to the National Board of Fire Underwriters, is indicative of the extinguishing potentialities of the different types and size of extinguishers.

Because many fire extinguishers classified under the old method will remain in service for years, and because some codes, ordinances, and regulations will continue for years to specify extinguishers according to the old classification system, the National Board of Fire Underwriters has made available a table making it possible to convert an old rating into a new one.

For further information, write to National Board of Fire Underwriters, 85 John Street, New York 38, N. Y., and address the request to the attention of the engineering department.

Stream Pollution

OBSERVATIONS ON VITAL DATA FOR STREAMS*

By Edward J. Cleary

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Assembly and interpretation of data relating to water pollution control have not been distinguishing attributes of sanitary-engineer administrators. This deficiency and the means for remedying it deserve exploration.

In so doing it might be recalled that the President's Advisory Committee on Water Resources Policy felt compelled to remind engineers and administrators that too often they did not know what they were talking about. Of course, the manner of stating it was somewhat more elegant. But the meaning was plain. The committee said that until there were adequate basic data on water resources the opportunities for developing sound policies and programs would be greatly hampered.

It seems a little odd, however, that neither in the President's Advisory Committee report—nor elsewhere for that matter—has the importance of such activity been reflected by the choice of terminology more dynamic and meaningful than the assembly of "basic" data. The data that is lacking actually is "vital" information. Why not, therefore, tag it in a manner to connote its significance?

In saying this there is some awareness that legislators who pass on budgets may be more responsive to providing funds for "vital information" than they might be to an item that bears the prosaic title of "basic-data assembly."

But at this point a question is necessary: How many state and interstate pollution control agencies would agree that basic data are vital to the conduct of their programs? Perhaps not too many, if the record of past performance is any guide.

What Constitutes Vital Data?

It is suggested that there are at least two areas of discussion that merit exploration—What constitutes vital data; and, why are vital data needed?

In regard to what constitutes vital data, the needs of the water pollution-control administrator in these categories are summarized as follows:

1. *Inventories:*—These would include, as a minimum, a tabulation of those communities and industries discharging waste into a stream, with details on the status of control facilities for each. Such an inventory would be revised once a year. Ideally, this inventory might include financial and design data; but it could be argued that this additional information is not essential for an appraisal of the status of the various states in pollution control from year to year.

2. *Industrial waste load to streams:*—The second major category of vital information is one that would provide a record of industrial waste loads that are discharged directly into a stream.

* Excerpts from remarks presented at the Surgeon General's Conference with State and Interstate Water Pollution Control Administrators, Washington, D. C., Feb. 21, 1958.

This record is for the purpose of establishing who is putting what into a stream and the precise location of the discharge. Provision should be made to revise this record in accordance with changes that occur in existing discharges and the addition of new sources of discharge.

3. *Water Use:*—A third category of vital information is a catalog of water use. This invites not only the inclusion of municipal and industrial water supplies in terms of location and quantities involved, but likewise should give cognizance to all other uses. Among the latter, of course, are agricultural services, recreational and esthetic pursuits, fishing, navigation, and hydropower.

4. *Quantity and quality aspects of streams:*—The final category is one that embraces vital information on the quantity and quality aspects of streams. This includes hydrologic information with particular reference to determination of minimum-flow characteristics. And it claims consideration of collection, analysis, and evaluation of data relating to quality conditions and their variation in a stream.

Why are the Data Needed?

Among administrators there is divided opinion as to the need for vital data.

A few will question why it is necessary to belabor the point since it is obvious that these data are needed.

By far the majority in this audience reflects the following viewpoint: "This is all very nice, but already there are so many burdens that there is no time to develop such records." To these the following response is given: An administrator is doing himself and his program an injustice to look upon this activity as something that might be done only when and if time permits; this attitude is self-defeating. Quite frankly, these officials are already sacrificing large blocks of their time, energy, and peace of mind because of the lack of adequate records.

Administrative Examples

Just a few months ago the chief engineer of a state health department complained rather bitterly that the demands on his time had just about reached the breaking point. And then he cited this experience: His governor called on a Friday afternoon and asked for a summary statement on the current status of sewage treatment for a speech he was to make on the following Monday. To meet the request the chief engineer said he had to spend all of Saturday and most of Sunday culling through department files to get some information together. He was mighty unhappy over what he called "the unfortunate timing" of the governor's request. It is suggested that the real cause of his discomfiture might have been the lack of a record system whereby information could have been brought together in a matter of minutes by one of his assistants.

Recently this incident occurred in another state. The administrator and a part of his staff had been submerged for several weeks in the task of meeting a request from a committee of the legislature. What was the request? It was the preparation of a tabulation showing the number of new pollution-control facilities that had been built each year over the past five years!

These are not extraordinary instances of an individual or an agency being strained in order to meet requests for facts about a program. What is extraordinary is the state of mind that permits the inevitable to happen over and over again without doing something about it.

There are reasons to believe that pollution-control agencies apparently do not enjoy the public confidence that their efforts would seem to justify. What is the reason? Could it be that the agencies are seldom sufficiently

armed with facts when issues are presented for appraisal?

As further evidence the remarks of a gentleman who represents a potent and articulate segment of conservation-minded individuals are pertinent. He indicated that a majority of his group had reached the conclusion that the time had passed for water pollution-control to be entrusted to what he described as "uninformed and uninspired apologists wearing the badge of sanitary engineers." He then went on to say that the record—or lack of it—showed very little evidence of accomplishment, despite years of alleged effort.

These remarks came as a shock. But upon later reflection it was conceded that here may have been a point—at least so far as the evidence from records was concerned. For example, the mass of testimony presented at the hearings on Public Law 660 is not very consoling on this score—certainly one can learn very little about the positive accomplishments in pollution control. Yet, there is reason to believe that in at least two states more than 92 per cent of the sewered population is served by treatment facilities. And it is speculated that equally significant accomplishment could be cited for other areas if the facts were compiled.

Therefore, this question is asked: Is it fair to an administrator, to the program he administers, and to the public that he so diligently serves, not to have the basic facts to aid in a realistic appraisal of the situation?

This plea, however, is not that there be collection and analysis of facts simply to be armed for purposes of pointing with pride or for viewing with alarm. More importantly, it is asserted that officials are handicapped professionally when they deprive themselves of information essential to engineering and economic decisions relating to pollution control.

Industrial Wastes

A case in point is the situation with regard to industrial waste discharges. With few exceptions, control agencies have not been distinguished in keeping abreast of who is discharging what into the streams. Yet, more than half of the states operate under laws that make it mandatory for industries to report such information. This, then, is the question: Can administrators carry on an aggressive and professionally competent program of control without compiling and using such vital information? A positive reply to this is doubtful. There are cited the numerous special investigations and surveys that must be inaugurated every time a problem condition develops in a stream.

It might be asked if some of these problems could not be anticipated and remedial measures instituted through the operation of a proper system of records and their evaluation. At least, much time-consuming and otherwise expensive work might be minimized.

On this matter of administrative practice with regard to industrial-waste discharges, some recent findings are of interest. They are based on information supplied in response to a recent questionnaire. These findings are briefly summarized.

Thirty-seven of the states operate under legislation requiring an industry to secure a permit or approval of plans prior to discharge of wastes into a stream. But it appears that only half of the industries that are required to have a permit are presently meeting this obligation. And in only three states is it a requisite for an industry to apply annually for review and reissue of a permit. Only 16 states are interested in the quantity and characteristics of the effluents discharged from industrial plants to the extent that they require a monthly report; four states are satisfied with a yearly report.

Do not these findings suggest there may be some validity to the charges by conservation groups and others that administration of industrial wastes control can be characterized as something less than positive?

A simple yet effective performance-rating system for industrial wastes control has been described by Adams (1). By this method all concerned—the agency, the industry, and the public—are kept abreast of activities in the control of industrial wastes.

Federal Agency Activity

It is to be hoped that the emphasis now being placed on data assembly by the Public Health Service will make it possible to publish the inventory of sewage disposal facilities more frequently than in the past.

There is both a professional and public need for such information. During the hearings on the Water Pollution Control Act, for example, the enlightenment of up-to-date facts would have been most helpful. And now that the federal-aid construction program is under way the desirability of having a proper baseline from which to draw comparisons in the future is even more pressing.

With regard to the Public Health Service program being established to secure stream quality information from a network of stations throughout the nation, this likewise can be viewed as of great significance. Experience in the Ohio Valley during the past seven years with a quality-monitor program provides some basis for saying that this is not a glamorous task. But the dividends from diligence in this work provide rewards beyond measure.

In fact, all aspects of vital-data assembly and interpretation promise rich rewards. And these remarks have been designed to inspire further activity toward realization of these rewards.

Reference

1. Adams, M. P., "Industrial Wastes, The Law and Pollution Control Programs." *Sewage Works Jour.*, **14**, 3, 653 (May 1942).

CULTURE FOR ENGINEERS

The cultural requirements for civil engineers are receiving increased attention. It is stated that the civil engineer frequently is required to deal with persons unfamiliar with engineering demands, but who know a great deal about the social and economic requirements of a public or private facility. It is believed that in establishing a complete understanding between himself and those with whom he works that the civil engineer frequently feels the need for more background in the humanities and liberal arts than that generally offered in a regular four-year civil engineering curriculum.

The University of Michigan has announced that in recognition of this desire the Engineering and Literary Colleges are now offering a five-year combined program leading to the degree of Bachelor of Science in Engineering (Civil Engineering) and Bachelor of Arts.

Included in the program are courses in languages, literature, fine arts, philosophy, and history, in addition to those in science and engineering. A student taking the program must complete four semesters in the Literary College and six semesters and a summer session in the Engineering College.

COLOR MEASUREMENT WITH THE STREAM COLORIMETER

By J. C. Coss and N. L. Nemerow *

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Color pollution is one of the most easily detected and, therefore, one of the most significant forms of stream pollution. Little effort has been expended towards removing color from wastes or streams. Color in streams is objectionable from an aesthetic standpoint. Only small quantities of color are removed by current treatments devised for eliminating other forms of pollution. Adequate means of color measurement would enhance progress in stream color quality control and removal.

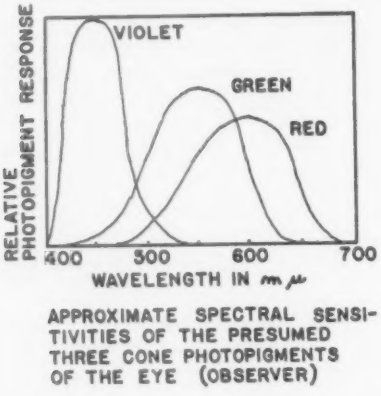

FIGURE 1.—Comparison of eye photopigment responses at each spectral color with relative amounts of "primary colors" required to produce spectral colors.

In order to standardize the color of paints, inks, plastics, fabrics, and to control color in streams, it must be possible to measure color qualitatively and quantitatively. This feat was made possible by an international commission on illumination (CIE) in 1931 through its definition of color in accordance with accepted psycho-physical color theory.

According to this theory, the eye is believed to contain photopigments sensitive to violet, green, and red colors, combinations of which cause an individual to perceive any color. The responses of these photopigments to each color of unit wave length throughout the spectrum are shown in Figure 1. In this, color is defined to be the relative amounts of pure red, green, and blue light that produce unit wave length colors throughout the visible spectrum. The curves presented in Figure 1 are similar.

Two methods of color measurement are made available by this definition: (a) the spectrophotometric method which utilizes lights of unit wave length and (b) the filter photometric method which utilizes three color filters (amber, green, and blue). To deter-

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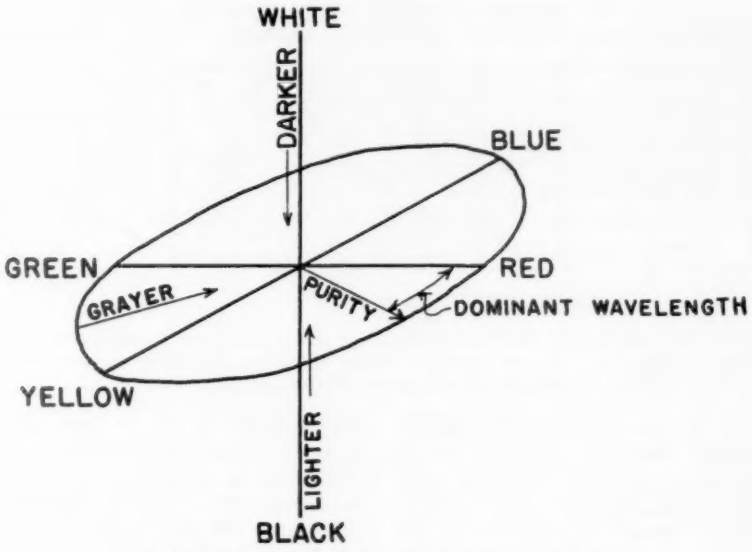

FIGURE 2.—A concept of color-perception space.

mine color by the first method, the relative areas under the three curves for a particular color sample are determined. With this information simple calculations yield the color quantity in terms of luminance (brightness), and color quality or chromaticity in terms of dominant wave length (hue) and purity (grayness). In the use of the second method each filter represents the areas under one of the three curves. The relative amounts of light passing through each filter from the sample color provide the basic information from which the color measurement is obtained.

The fact that color is defined by three variables, dominant wave length, luminance, and purity, indicates that color is a three-dimensional phenomena. The perceptual counterparts of these variable values are, respectively, hue, brightness, and saturation. When considering the three-dimensional relationships of these values (Figure 2), it is seen that the color quality or chromaticity is represented by the circular plane. The dominant wave length varies angularly around this circle. The purity varies radially on the plane. The luminance varies perpendicularly to this plane surface.

Available Methods for Measuring Color

The familiar color measurement method compares the sample color with a platinum cobalt standard concentration in parts per million. A reasonably accurate relative concentration can be determined only when comparing samples with similar hues. "Standard Methods" (1) specifies that the platinum cobalt method be used only in connection with potable waters. However, according to "Standard Methods:" "Potable waters of highly unusual color, such as may occur as a result of mixture with certain industrial wastes, may have hues so far removed from those of the platinum cobalt standards that comparison by the standard method is difficult or impossible."

"Standard Methods" recommends the use of spectrophotometric and filter-photometric methods (as described

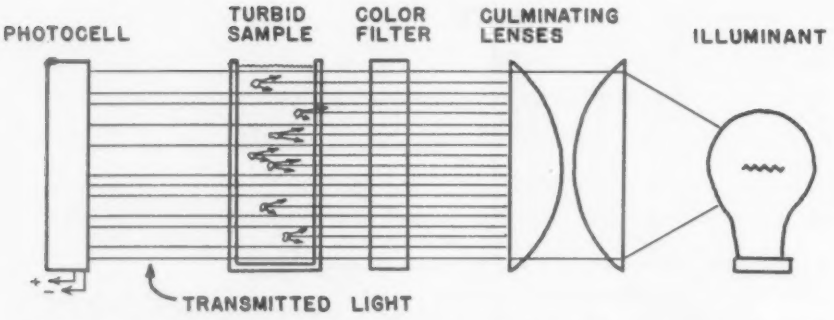

FIGURE 3.—Photocell-sample-filter-illuminant configuration for measurement of color with transmitted light. Turbid particles reduce luminance by absorbing and reflecting light. Chromaticity of transmitted light is not affected.

above) for measurement of color in industrial wastes. These measurements are in terms of dominant wave length, purity, and luminance. Colors cannot be compared, however, on the basis of straight-line relationships similar to that used in the platinum cobalt method. These latter methods, therefore, do not readily lend themselves to color control. It is conceivable that a series of colored solutions of varying hues might be assembled and used in a manner similar to the platinum cobalt method—the requirement being that the standard and sample "colors" should be very similar. However, it would be practically impossible to develop reproducible, stable standards throughout a sufficiently wide range of the spectrum for this purpose.

All of the above-mentioned color-measuring devices or instruments measure light transmitted through the liquid sample. These instruments are rendered ineffective when used for measurement of liquid containing turbidity. "Standard Methods" notes a limitation on the use of the filter photometer and the spectrophotometer

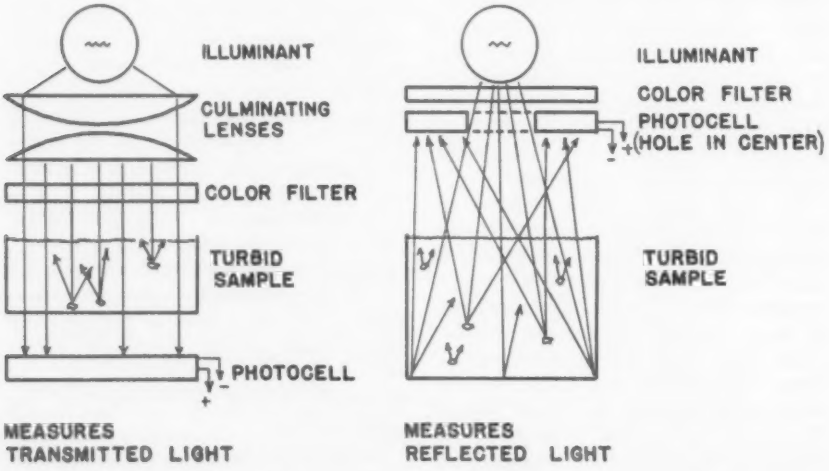

FIGURE 4.—Comparison of component configurations of instruments measuring transmitted light and instruments measuring reflected light.

also: "It is recognized that the color characteristics of some wastes are affected by the light reflection from the suspended material in the wastes. However, until a suitable method is available for making solution reflectance determinations, the color measurements will be limited to the characteristics of light transmitted by clarified wastes." When using transmitted light, the turbidity present in the sample alters the transmitted color quantity and not the color quality. This fact is illustrated in Figure 3. Although the measured chromaticity of samples will be the same regardless of the turbidity present, the luminance will be less in the presence of turbidity.

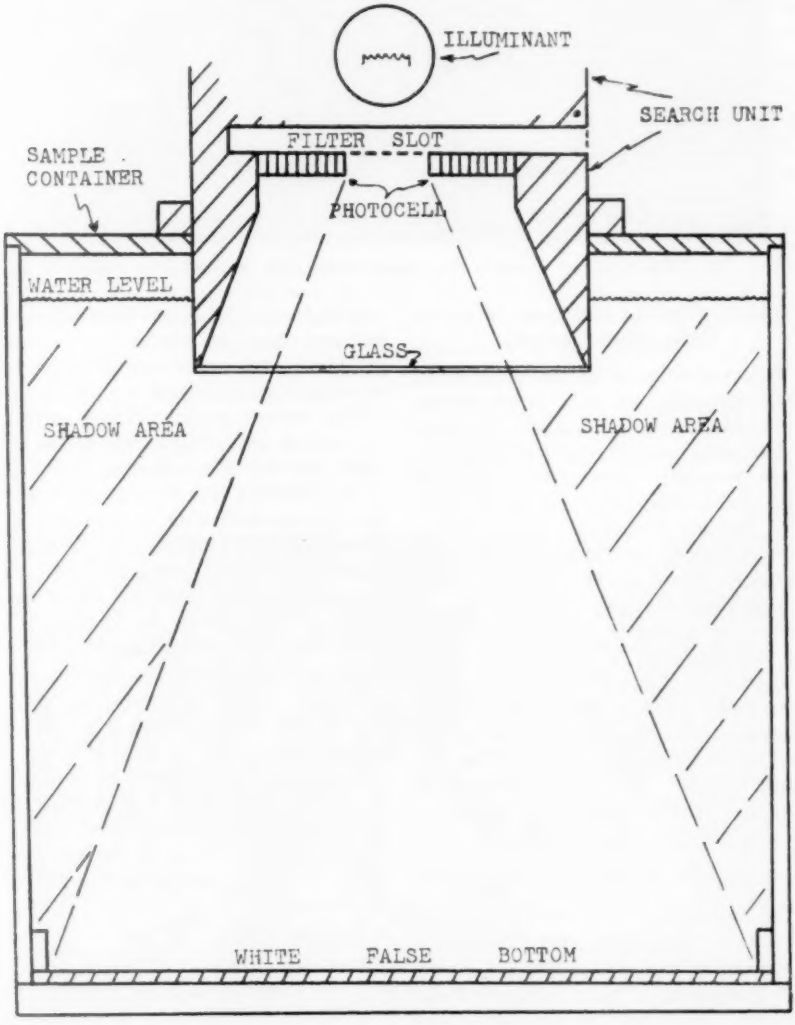

FIGURE 5.—Cross section of final apparatus showing color-measuring components and sample configuration.

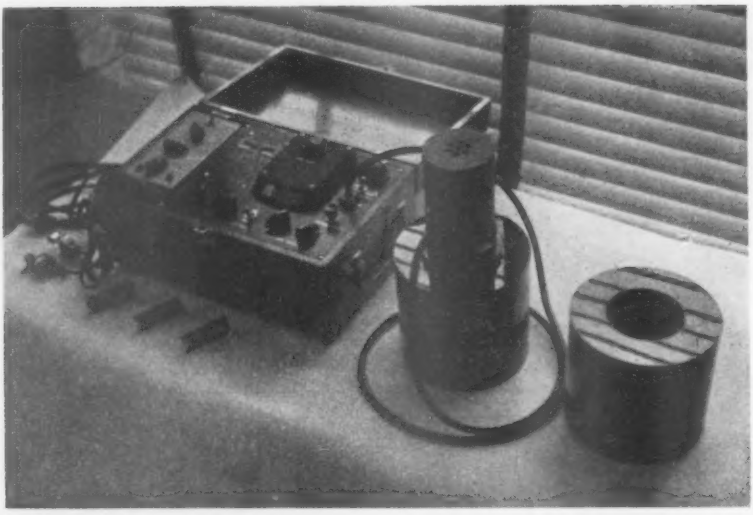

FIGURE 6.—View showing the stream colorimeter ready for operation.

Proposed Method and Apparatus for Color Measurement

Reflected color is normally observed when standing on a bank or bridge overlooking a river. Industrial wastes and streams usually contain turbidity. Since turbidity affects the reflected color, the method used to measure color must include the effects of turbidity. (For example, red turbidity in blue solution reflects a green color.) This required measurement can be accomplished by a simple rearrangement of the configuration of the illuminant, sample, and photocell of the standard filter photometer. With the new arrangement (Figure 4), the light measured is that reflected from within the liquid sample. The color measured is a result of turbid particles and soluble chemical compounds in solution.

Description of the Working Apparatus

The apparatus consists of a galvanometer, a bridge circuit, search unit, and a sample container. The color-measuring components and their location with respect to the color sample are as shown in Figures 4 and 5. Figure 5 shows a cross section of the working apparatus at approximately 80 per cent of full size. Photographs of the stream colorimeter appear in Figures 6 and 7.

The galvanometer, bridge circuit, and search unit components are as provided in the Photoelectric Reflection Meter, Model 610-D.* This instrument is supplemented with a special transistor current amplifier for magnification of photocell output to the galvanometer. The need for this amplifier can be cancelled by the use of a more sensitive galvanometer than is provided with the above described instrument. The instrument was designed for measurement of light reflected from a flat, opaque surface.

The sample container, as shown in Figure 5, is designed to enable the measurement of light reflected from a liquid sample. Some of the necessary features of the sample container are as follows:

1. Light tight.
2. White bottom.
3. Automatic constant liquid depth.
4. The illuminant-filter-photocell-

* Manufactured by the Photovolt Corporation, 95 Madison Ave., New York 16, N. Y.

sample configuration to be such that no shadow area in the sample comes between the container bottom and the photocell.

There are some specifications of the search unit and sample container that can be changed from those shown without altering the resulting color measurement. Some changes from those shown would be desirable from the standpoint of convenience. These are as follows:

1. Diameter and depth of the sample container can be changed within certain limits.
2. Intensity of the illuminant can be changed (the color temperature must be the same as in the original Photovolt reflection meter).

Preparation of a stream colorimeter using the Photovolt instrument provides a compact, rugged, versatile instrument which can be used equally effectively in the laboratory or field, using alternating current or battery.

Color-Measuring Procedure

The color-measuring procedure used is the same as that used with any tri-stimulus colorimeter. Briefly described, this procedure is as follows: A container similar to the sample container is filled with distilled water. This is the reference sample. The search unit with one of the tri-stimulus filters is set on this container and the galvanometer is set on 100 per cent reflectance. The search unit is transferred to the sample container and the reflectance value recorded. This procedure is repeated for each of the remaining two tri-stimulus filters. Using the filter factors provided with the Photovelt instrument, these reflectance values are translated into the color description in the terms shown above.

Illustration of a Color Determination Calculation

The stream colorimeter was used to determine the color of a sample solution which to the eye appeared to be blue-green. The exact color was determined using light reflectance values measured. The filter factors to be used with this instrument in determining tri-stimulus values, X, Y, and Z

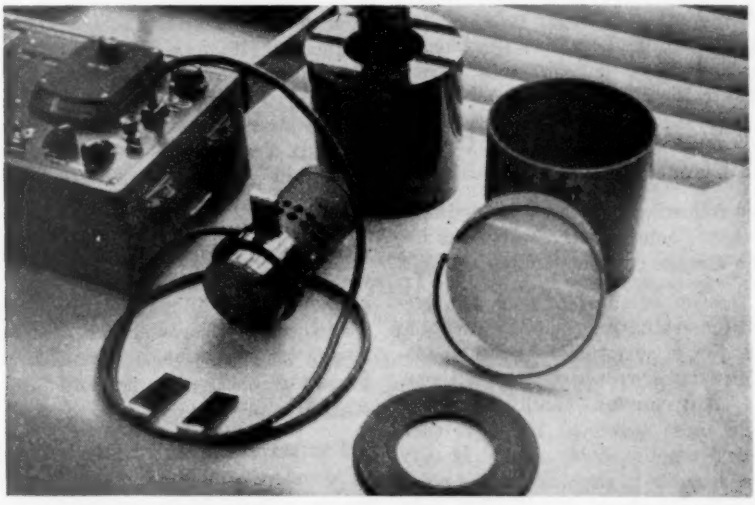

FIGURE 7.—Close-up view of the search unit and component parts of the reference and sample containers.

are shown below. A, B, and G are the amber, blue, and green filters respectively. x and y are known as the trichromatic coefficients.

$$X = 0.8\,A + 0.18\,B \quad \text{(1a)}$$
$$Y = G \quad \text{(1b)}$$
$$Z = 1.18\,B \quad \text{(1c)}$$

A test on the blue-green dye yielded the following reflections for the A, B, and G filters in per cent:

$$G - 88.8 \quad \text{(2a)}$$
$$A - 82.0 \quad \text{(2b)}$$
$$B - 93.5 \quad \text{(2c)}$$

The tri-stimulus values of the sample color is thus determined as follows:

$$X = 0.8(82.0) + 0.18(93.5) = 82.5 \quad \text{(3a)}$$
$$Y = 88.8 = 88.8 \quad \text{(3b)}$$
$$Z = 1.18(93.5) = 110.0 \quad \text{(3c)}$$
$$\Sigma \quad 281.3 \quad \text{(3d)}$$

Then:

$$x = 82.5/281.3 = 0.293 \quad \text{(4a)}$$
$$y = 88.8/281.3 = 0.316 \quad \text{(4b)}$$

The luminance is the same as the reflection measured using the green filter—in this case 88.8 per cent. The dominant wave length, and the purity, as determined from a chromaticity chart using calculated x and y values, are 490.5 mμ and 6 per cent, respectively. These three values, luminance, dominant wave length, and purity, designate the color.

Application of a Method for Control of Color Pollution in Streams

The following procedure is suggested to measure color in streams by the use of the stream colorimeter:

1. Stream color standards are prepared by evaluating just-objectionable colors for a particular stream as determined by a group of qualified persons. Any stream containing color outside these standard limits is then considered polluted by color. It may not be feasible to prepare stream color standards for every stream, but only to group them into categories such as coastal, piedmont, and mountain streams. One standard might be used for all the streams in each region.

2. Once the natural color characteristics of a particular stream and its color standards are known, a plant operator can predict the degree of color reduction (if any) necessary to make the plant effluent acceptable in the stream. For example: with the aid of the stream colorimeter an operator can mix a small sample of effluent and stream in proportions that would exist if the effluent were discharged into the stream. A quick color test and a check of existing color standards will disclose whether the effluent in that proportion lies within standard limits and, therefore, is acceptable for discharge. Any color reduction required can also be determined with the aid of the stream colorimeter.

Further research is being conducted to develop a method of determining stream standards for use in the above procedure.

Summary

Color pollution is one of the most objectionable forms of stream pollution. Satisfactory methods of measuring the quality and quantity of stream color did not exist heretofore. A new method of stream color measurement is now possible using the stream colorimeter. The stream colorimeter is compact and can be used in the field or laboratory using alternating current or battery. Color measurement is simple. Color of waste effluent can be measured readily and thus more readily controlled for discharge into streams. Methods of determining color standards (acceptable color ranges) of streams are now being studied.

Reference

1. "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes." 10th Ed., Amer. Pub. Health Assn., New York, N. Y. (1955).

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REPRESENTATIVE SAMPLING AND ANALYTICAL METHODS IN STREAM STUDIES *

By Paul D. Haney and John Schmidt

Black & Veatch, Consulting Engineers, Kansas City, Mo.

Klein (1) states that although river surveys may be carried out for a number of reasons, whatever the purpose in view, the detection and identification of the pollutants, followed by quantitative methods to determine the extent of pollution, must constitute a fundamental feature of the survey. Obviously he is referring to the basic importance of sampling and analysis. These phases of a water pollution survey are certainly the cornerstones of the investigation.

Cross (2) in speaking of structural engineering has stated:

"Most literature in the structural field deals with strength and stability for the very good reason, not always obvious to the amateur, that if a structure is not sufficiently strong, it makes little difference what other attributes it has. One might almost say that its strength is essential and otherwise unimportant."

By analogy these statements could be applied to the topic under discussion—sampling and analysis. Unless this feature of the survey is thoroughly and accurately done, what follows will not stand up. If the program of sampling is not carefully planned and the analyses accurately conducted, no matter how the data are manipulated graphically and mathematically and no matter how elegantly the report of findings is presented, the end result will be "structurally" weak.

The basic information from which all else is derived must be sound in order to produce a sound, finished product. This is not to imply that the raw data obtained from a program of sampling and analysis should not be subjected to much study by appropriate statistical methods, and that a great deal of time and effort should not be spent on interpretation and presentation. Rather, it emphasizes the difficulties inherent in building something structurally solid out of poor material. Although those charged with responsibility for water pollution control activities cannot look upon themselves as dedicated solely to the task of data collection, they do have the duty of providing a sound factual basis on which to build their programs.

Sampling

Assembly of reliable water quality data begins with sampling. A sample, by definition, should be representative, for it is presented as evidence of the quality of the body of water from which it was obtained. It does not take much in the way of deliberation to reach the conclusion that the term "sample" means much more than a small volume of water contained in a glass bottle, even though the bottle may be glass-stoppered and made of special glass.

A dominant aspect of a sampling program is the fact that sampling is hard work. There is no escape from this and the attendant expense. An important goal, therefore, should be the conduct of the sampling in such a way that it will lead to results that

* Presented at a Seminar on Oxygen Relationships in Streams; The Robert A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio; Nov. 1, 1957.

bear some reasonable relationship to the time, effort, and money expended. As has been emphasized by a number of authors, notably Velz (3), in order to achieve results commensurate with effort the sampling program needs to be carefully designed.

The first things that have to be settled are, of course, the basic purposes of the survey. What are the problems that make the survey necessary? Hoskins (4) emphasized the importance of clear-cut objectives, stating:

"Surveys to determine the sanitary condition of polluted streams may be undertaken for any one or a combination of several purposes. The nature of the organization required to conduct such a survey, as well as the survey itself, is, then, very largely dependent upon the kind of information desired. It is therefore highly essential that a clear and complete statement of the objectives be agreed upon first; then the plans for the survey can be built around these requirements."

Once over-all survey strategy has been agreed upon, a tactical plan can be developed. The stream sampling program is a major phase of this plan.

Study of various sections of "Standard Methods" (5) will provide valuable information about samples of various types. Special procedures for collection, storage, and preservation are described in "Standard Methods," but obviously no single book, or shelf of books, can specify detailed instructions for every situation. It is especially necessary that the person who is to collect the sample have a thorough understanding of the correct techniques and precautions. The advice of the chemist, bacteriologist, or biologist who will work with the samples should be obtained early in the planning stages of the study.

Poets, in particular, have written of rivers as though they were endowed with human characteristics—and there is a good deal of truth in their writings. Streams can be willful, stubborn, secretive things, and like people they seem to take great delight in confounding the experts. Velz (3) has referred to the dynamic nature of streams and to the fact that they are subject to wide variations in time, as well as from place to place along their course. He has also presented a summary of the major factors that affect stream sampling. These include:

1. Sampling as related to the daily hydrograph.—The ideal period for sampling is during a period of steady runoff after the establishment of a stable river regime.

2. Sampling in relation to sources of pollution and tributaries.—This is especially important because it involves the problem of mixing of polluted waste water and tributary stream flow with the waters of the river being investigated. Care must be taken to locate sampling stations far enough below sources of pollution to insure reasonable mixing. If there is doubt about mixing, as there often is, variability should be checked by multiple sampling points across the stream. A recent survey of the Mississippi River (6) provides some exemplary data. In this instance phenol concentrations varied from approximately 50 ppb, near both shores, to practically zero in mid-stream (7). Attention is called to the influence of water temperatures on mixing. A significant temperature difference between two streams of water may result in vertical stratification. The same thing can occur when the density of one stream is substantially greater than that of another. This type of stratification has been observed in streams polluted by salt water.

3. Sampling in relation to physical characteristics and river developments.—Width of river, depth, and flow regulation influence the design of a sampling program. Hydroelectric plants are particularly troublesome because of the radical daily and weekly flow patterns they produce. Velz (3) and Ingols (8) have both presented discussions of this problem and it is now

under study by the U. S. Public Health Service.

4. Sampling in relation to waste discharge.—Wastes from industries are particularly troublesome in this respect. They can exhibit wide hourly, daily, weekly, and seasonal fluctuations.

5. Abnormalities in natural purification.—The Velz (3) discussion includes the effects of immediate oxygen demand, sludge deposits, biological absorption on the stream bed, and algae. These factors complicate oxygen relationships enormously and probably are responsible for a part of the erratic results obtained in some surveys.

The number of samples required to establish a reasonably accurate picture of a stream's behavior is a question not to be solved easily and rapidly. Probably an individual possessing good statistical sense in combination with considerable experience in stream sanitation could make some quick, educated guesses as to the required number of samples. Such estimates could serve as a good basis for further study and argument. Advice of this nature should be obtained, if at all possible, in connection with sampling program planning.

In general, any temptation to secure broad coverage by the establishment of a large number of sampling stations should be resisted. Invariably this leads to inadequate coverage of individual stations and results that are unreliable. Unless there is good reason for departing from it the guiding principle (3) that should be stated is: "A few locations with sufficient number of samples to define results in terms of statistical significance. . . ."

It should be added that sampling station location may be influenced somewhat by stations established in connection with earlier surveys.

With regard to the intensity of sampling at a particular station, it is suggested that concentrated sampling during a short period of time is likely to produce more useful results than extended periodic sampling.

To return to the question of the number of samples required, experience has shown that the practical considerations of available manpower, time, money, and a multiplicity of physical obstacles will place a ceiling on any sampling program. This frequently is the answer to the question as to why more samples were not obtained. Scientific criteria often have to be tempered by practical considerations of time and money. However, this lends emphasis to the previously expressed thought that careful preliminary planning is necessary to insure best use of the sampling resources available.

Grab vs. Composite Samples

Some mention should be made of the two broad sample classifications; that is, grab samples and composite samples.

Composites find their greatest field of usefulness in connection with correlative studies of pollution loads, but they are also of value in stream work. They have been used advantageously in connection with mineral analyses. But an obvious word of caution regarding composite samples is in order. It should be understood that the act of compositing automatically masks the quality abnormalities in the stream being sampled. Often these variations are of as much, or more, interest than the average value given by the composite.

Grab samples, as the name suggests, are manually-collected single portions of water. Analytical results on grab samples indicate concentration of the constituents at the time and place of sample collection. Frequent grab samples at the same station will show variations in quality as a function of time. Nevertheless, it must be remembered that any reasonable size of sample represents a negligible fraction of the total flow so that in subsequent

computations, where the total flow figure may be applied to the results of the analysis, the multiplier is enormous. If this sample and others like it are not representative, no amount of mathematical manipulation can avoid large discrepancies in the final results of the survey. In the analyses of the data such descrepancies complicate the interpretation and explanation.

Having emphasized the importance of securing truly representative samples, it might be well to examine briefly a situation where survey purposes are better served if the sample obtained is representative of only part of the total flow of the stream. Such a situation could arise where mixing does not occur readily and pollution is stratified horizontally or vertically. Assuming that the pollution hugs the shoreline, the operator of a downstream water plant having a shore intake will not be nearly as much concerned with the pounds per day or average parts per million of one particular contaminant, such as phenol, in the water passing his plant as he will be in the concentration of phenol in the water at the intake structure.

Use of Results

This touches upon a corollary problem associated, not so much with sampling, as with the reporting of analytical results and the use and abuse of averages. "Averages" are both convenient and dangerous and they alone could be made the topic of an interesting discussion. There are many good books that treat with averages and other measures of central tendency. However, anyone interested in undertaking a study of these and other interesting statistical parameters might well begin with Fair's (9) chapter on "Mathematical Aspects of Sewage Research."

The stream sanitation staff of the Tennessee Valley Authority (3)(10) has used a scheme involving identification of a water mass by means of a salt slug as it travels downstream. Samples for the usual analyses were collected from the same water mass at successive down-river stations. Data of this kind should be quite valuable in determining the effects of a definite quantity of pollution on water quality and the fate of polluting materials as they travel downstream.

Churchill and Buckingham (11) (12) have developed a new approach to the determination of a stream's capacity to assimilate organic pollution. This method is based on "multiple correlation of all the principal factors producing and controlling the extent of the dissolved oxygen sag below a source of pollution." These factors are BOD load, stream flow, and water temperature. A salient feature of this approach is elimination of the need for long-term BOD and time-of-flow determinations. Application requires a minimum of sampling stations and samples. It is hoped that this method can be tested on a number of streams, for it appears to offer an opportunity to reduce the labor and expense associated with stream surveys.

Emergency Sampling

Although the importance of careful survey planning has been repeatedly stressed, it is recognized that many stream investigations must be conducted on an emergency basis. The personnel of state water pollution control agencies are aware of this and probably have learned more about emergency surveys than they care to know.

Timing is all-important in such cases and planning, if any, must be done while enroute to the scene of the difficulty. The main consideration is to get the samples; probably there will be no second chance. The choice may lie between some data and no data; some specific knowledge is always better than none. Generally, water pollution emergencies are caused by "slugs" of waste material. If the

slug is missed, results will be inconclusive—and speculation cannot replace evidence.

In determining what is to be done under emergency conditions there is no acceptable substitute for experience. Waterworks operators, fishermen, and other water users along the stream can often be helpful. Reliable individuals should be alerted by telephone and their assistance requested. In any emergency operation of this type good communications between field men and central or district offices are, of course, highly desirable.

It is not unlikely, also, that the pollution that results in a water quality emergency will also result in legal action. When a case goes to court the whole matter is in the hands of another profession and the game is played according to their long-established rules. It is well to have some advance information regarding these rules, particularly as regards the handling of samples, and the reporting of the analytical results.

Legal Considerations

In general, the legal pitfalls seem to increase about as the square of the number of people who handle the sample from the time of collection until analyzed and reported.

Bloodgood (13) has presented summaries of a number of court actions involving stream pollution. In these citations little if any mention was made of the common parameters of pollution (dissolved oxygen, BOD, and coliform bacteria). However, judicial notice was taken of such stream properties as "objectionable solids or slimes upon a river's bottom or banks," "scum on the water surface," "discoloring of the stream," and "pollution with . . . small quantities of oil." These and other characteristics such as odors, dead fish, and taste in drinking water are the criteria by which the public and most of the legal profession measure water pollution. Any of these may be a "cause of action."

The public, judges, attorneys, and juries can readily understand these simple criteria; and although most of them are not readily subject to quantitative measurement, they can be made to serve very useful purposes. Photography sometimes offers a means of making an easily understandable record of offensive stream conditions. One carefully composed well-documented photograph, particularly if it is in color, may be worth a hundred dissolved oxygen samples insofar as securing public support or influencing a jury is concerned. A photograph is, in a sense, a sample, for it may be "presented for inspection or shown as evidence of the quality of the whole."

Sampling Equipment

Technical considerations demand sampling equipment tailored to the work to be done and many ingenious sampling devices have been built and are in every-day use. However, a good deal of supplementary equipment ranging from boats to waders is often required. This should receive careful consideration also, as the role of the sampler is not an easy one. Such a task is not conducive to much interest or enthusiasm.

Sampling apparatus ranges from simple manual devices to complex mechanically-operated equipment. Most everyone is familiar with the dissolved oxygen sampler pictured in each edition of "Standard Methods" (5). Less familiar are some of the devices used by biologists and oceanographers. The functioning and application of the many sampling devices described in the literature are beyond the scope of this discussion, but a few sources of good information on the subject of sampling equipment include "Standard Methods" (5), the well-known "Ohio River Report" of the U. S. Public Health Service (14), and papers by Black (15) on the sampling

of industrial wastes, and Thomas, Kleinschmidt, and Parker (16) on an integrating sampler. Recently, Tsivoglou, Harward, and Ingram (17) have described sampling devices found useful in connection with stream surveys for radioactive waste control.

There are no doubt other valuable descriptions of sampling equipment. Information about sampling devices is scattered throughout the literature of science and engineering. In addition, there are in daily use many workable devices whose descriptions have never been published.

Analytical Methods

General Parameters

Laboratory analyses are major sources of information in water pollution surveys. In fact, little progress was made until laboratory personnel developed techniques for expressing water quality data in terms of numbers. That undoubtedly is why the search for improved methods for obtaining more and better numbers goes on from day to day.

The first standard manual on the laboratory examination of water was published in 1905 under the title *Standard Methods of Water Analysis*. Since then nine other editions have been published and the name has been changed to *Standard Methods for the Examination of Water, Sewage, and Industrial Wastes* (5). As stated in the preface to the tenth edition, each new edition "can represent only another stage of progress. To some extent, standard methods must be out-of-date by the time they are published." A new edition is continually in preparation by committee action.

The laboratory procedures particularly pertinent to oxygen relationships in streams (namely, the dissolved oxygen test and the BOD determination) are very satisfactorily presented in the current edition of "Standard Methods"; not only is attention called to the common sources of error but measures of the precision of results also are given. It should be noted that the directions and precautions stated in very brief form in "Standard Methods" represent the summation of a great deal of knowledge. To achieve full benefit of this knowledge it is necessary that directions given be followed consistently and carefully. Unless the circumstances are exceptional, shortcuts are not recommended. In general, deviations should be matters of necessity and not merely of convenience.

Of the common tests made in connection with stream surveys, the BOD determination probably causes the most difficulties. Simple in concept, the test presents considerable difficulties in practice. One prominent source of trouble is unsatisfactory dilution water; another is improper seeding. An example of the importance of seeding material has been discussed by Ettinger, Lishka, and Kroner (18) in connection with work on the pollutional characteristics of specific organic materials. Studies of pyridine and related compounds indicated that these materials are "aerobically attacked in dilute solutions by microorganisms." However, the BOD of these compounds may not be observed in the absence of proper seeding organisms. Normally, stale sewage is used as seed; but this was not at all satisfactory as seed material in the case of pyridine compounds. On the other hand, polluted river waters apparently contained an abundance of appropriate seed material. Such a situation can, of course, lead to large discrepancies between waste loads as measured at the source and the actual load applied to the stream. Obviously, results of this kind are difficult to interpret and explain to cities, industries, and fishermen.

Specific Compound Methods

Thus far in stream sanitation, discussion has been confined to rather nonspecific measures of pollution, such as

BOD, oxygen sag, pH, color, and threshold odor. Although the continuing importance of these "collective parameters" is not minimized, the one key to long-range progress lies in the development of improved methods for the detection and study of specific compounds. Examples of work of this kind are the previously mentioned studies (18) on pyridine and related compounds and the carbon filter work (19) now under way. Attention is called to the fact that the carbon filter, as currently used for research studies (19), represents a sampling device that to a degree combines the functions of concentrating and compositing. It offers a means of detecting and identifying classes of compounds that occur in concentrations far below the threshold of normal analytical methods.

It should be noted, of course, that the BOD test, useful as it is, is not a universal assay method. Certainly reporting of the BOD does not constitute a complete assessment of the pollution potential of a waste.

Ettinger (20) has recently discussed the importance of chemical pollutants that persist in a stream. For such materials the stream has virtually no self-purification capacity within the usual meaning of the term. Pollutants of this kind produce permanent water quality damage. They exhibit little or no BOD and dilution provides the only means of reducing their concentration. Obviously, BOD tests alone may not provide a satisfactory evaluation of the pollution characteristics of a complex waste. In enthusiasm for the study of oxygen relation, one must not overlook the damaging materials, organic and inorganic, that have no or very little effect on these relations, but which may have a profound influence on water quality.

Sampling and Recording Improvements

In 1949 a report was submitted on Clarion River pollution abatement studies (21) to the Sanitary Water Board, Pennsylvania Department of Health. From the results of this comprehensive investigation, especially pertinent recommendations are as follows:

"In our judgment it will be much more difficult to insure the proper and continuous use of the pollution abatement facilities recommended in this report than it will be to induce the industries to provide the facilities. It is essential, therefore, after the works recommended in this report have been constructed, that the Sanitary Water Board have effective means for insuring continuous and satisfactory use of these works. Periodic inspection and river sample analyses will not suffice, because of the probability of sporadic overflows or dumpings of strong industrial wastes. In order to detect such pollution, one or more continuous recording stations are necessary to obtain continuous records of the dissolved oxygen and BOD content of the river waters. Apparatus satisfactory for these purposes has not yet been developed ready for installation. Portions of the equipment are available, but research and development will be required before a complete station can be designed. We recommend . . . . the necessary research and development, and the construction of one or more stations on the Clarion River. . . . ."

McKee (22) made a similar, somewhat broader, recommendation in 1952 when he stated that "efforts be made to encourage the development of continuous recorders by which various criteria of water quality in streams can be measured and recorded." Hoak (23) has reiterated the necessity for continuous water quality recorders.

To dwell at length on the great value of equipment of this kind is to emphasize the obvious. Significant progress has been made. Levine *et al.* (24) have reported on the continuous measurement of dissolved oxygen in water. Recently, Levine and Kleinschmidt (25) published results of further development work. It is essential that work along these lines continue and at a more rapid pace.

Instrumentation

If recent-past and current trends in analysis could be characterized by one word, this would be "instrumentation." Formerly the chemist worked with relatively simple volumetric, gravimetric, and colorimetric equipment. Now many laboratories possess a variety of complex instruments that have vastly extended the efficiency, sensitivity, and scope of analytical activities. Entirely new fields of analysis also have been developed.

It is fortunate that research and development in analysis have moved forward fairly rapidly, for one is constantly confronted with new problems in the water pollution field. These stem from more intensive use of water resources for many purposes, including waste disposal, greater industrial activity, and technological progress, the like of which has not been seen before. New industries, dealing with substances that did not exist or were little more than laboratory curiosities ten to twenty years ago, have developed and are developing. Nearly every issue of the chemical industry periodicals contains news of the use of unusual chemicals. A recent article (26) discusses the industrial health hazards associated with boron, titanium, molybdenum, zirconium, germanium, columbium, and vanadium. Another (27) mentions some of the difficulties associated with fluorine-derived chemicals used in rocket-propellant combinations. These include oxygen difluoride, nitrogen trifluoride, chlorine trifluoride, and bromine pentafluoride. It is not implied that these specific materials are causing or will ever cause water pollution problems. They are cited merely to lend support to the previous statement concerning the rapidity of technological change. This much is certain: many new compounds of one kind or another, possibly on a tonnage-production basis, will be encountered in the future. The potential of simple chemistry—that is, the kind of chemistry associated with the electron shells of atoms—is obviously large. The opportunities for technological advancement created by the atomic age are great. Those interested in stream surveys have no choice but to interest themselves in these new developments while retaining their interest in improved application of existing knowledge.

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MEETINGS OF INTEREST
1958

June 16–20	**Bio-Oxidation of Organic Wastes,** Manhattan College, New York, N. Y. Professor W. W. Eckenfelder, Jr., Civil Engineering Dept., Manhattan College, Riverdale, New York 71, N. Y.
June 22–25	**American Institute of Chemical Engineers,** Bellevue-Stratford Hotel, Philadelphia, Pa. F. J. Antwerpen, Executive Secretary, 25 West 45th St., New York 36, N. Y.
June 22–27	**American Society for Testing Materials,** Hotel Statler and Sheraton Plaza Hotel, Boston, Mass.
June 23–27	**American Society of Civil Engineers,** Multnomah Hotel, Portland, Ore. W. H. Wisely, Executive Secretary, 33 West 39th St., New York 18, N. Y.
Sept. 1–13	**2nd International Conference on Peaceful Uses of Atomic Energy,** Geneva, Switzerland.
Sept. 7–12	**American Chemical Society,** Chicago, Ill. R. M. Warren, American Chemical Society, 1155 16th St., N. W., Washington, D. C.
Sept. 13–18	**American Chemical Society,** Atlantic City, N. J. R. M. Warren, American Chemical Society, 1155 16th St., N. W., Washington, D. C.
Sept. 28–Oct. 1	**American Public Works Association,** Muehlebach Hotel, Kansas City, Mo. Donald F. Herrick, Executive Secretary, American Public Works Association, 1313 East 60th St., Chicago 37, Ill.

THE OPERATOR'S CORNER

SNAILS ASSOCIATED WITH SEWAGE TREATMENT INSTALLATIONS *

By William Marcus Ingram, William Bridge Cooke, and L. T. Hagerty

Respectively, Biologist and Mycologist, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio; and Sewage Treatment Engineer, Division of Sewage Treatment, Dayton, Ohio

Snails occur in the trickling filters of a number of sewage treatment plants. Their presence has caused occasional operating problems, ranging from nuisances to interference with the proper functioning of the treatment units.

Occurrence at Dayton, Ohio

There are 73.6 acre-ft of filter stone in 20 trickling filter beds (160,270 cu ft per filter) at the Dayton, Ohio, sewage treatment plant (Figure 1). These filters are 165 ft in diameter and 7.5 ft deep. Twelve of them are standard rate (4.3 mgad) and 8 are high rate (10.8 mgad). Average flow is 40 to 42 mgd. These filters are the focal point of snail problems in the plant. Here individuals of the "sewage plant snail," *Physa integra*, live the year around and carry out their reproductive activities (1).

The trickling filters discharge into six secondary settling tanks from which the effluent is discharged into the Great Miami River. Secondary tank sludge is returned to the incoming raw sewage (ahead of the grit chamber) through 6-in. lines. The pump suction lines between the tanks and pumps are from 100 to 330 ft in length. The pump discharge lines are from 870 to 1,100 ft long. Snail difficulties occur in the pump suction lines and in the pumps proper.

Data collected indicate that a fair estimate of the yearly average weight of snails leaving the trickling filters and entering the final settling tanks is 1,200 lb per day. Maximum weight of snails carried from the trickling filters into the final settling tanks occurs in the spring (during March, April, and May) and on some days consists of as much as one ton of snails.

The 6-in. return sludge lines in the area between the final settling tanks and the sludge pumps become clogged four to five times a year with snail shells. Such clogging completely stops the flow. To loosen the compacted shells, it is necessary to use air at 100 psi. The water pressure available at the plant (75 psi) is not sufficient to dislodge the compacted shells. Currently a line can be cleared in from one to two man-hours at a cost of from $2.50 to $5.00 an hour. Before air pressure was available, three to four man-days were involved in line clearance at a cost of from $45 to $60.

* *Editor's Note.*—Any information that sewage treatment plant operators can supply relating snails to sewage treatment operational difficulties will be welcomed by the authors to facilitate assessment of the magnitude of the snail interference problem.

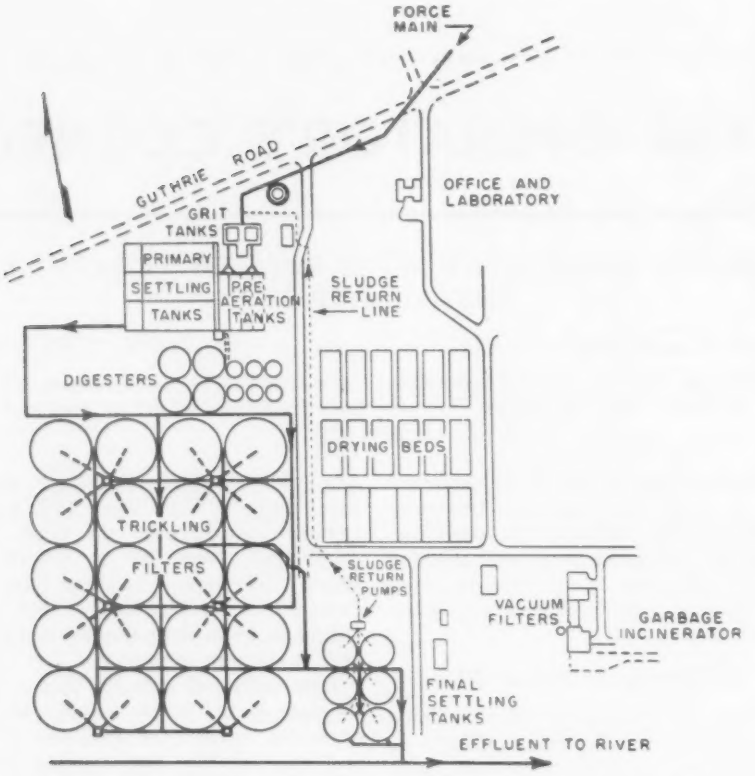

FIGURE 1.—Flow chart of the Dayton, Ohio, sewage treatment plant.

Another difficulty caused by snails is the abrasion of the sludge pump pistons, rendering them inefficient and necessitating piston replacement at a more than normal rate. In a year this abrasion will wear 0.25 in. from the diameter of a 10-in. piston. Repair of pumps costs $250 a year per pump and requires from 32 to 45 man-hours. Current maintenance costs have been cut about in half by diluting the daily volume of sludge to 580,000 gal from 290,000 gal. Higher pumping rates are employed and the material is moved more rapidly with less abrasive action.

Various sized individuals of *Physa integra* (Figure 2C) have been collected from the beds of both standard-rate and high-rate trickling filters at Dayton. Snails range from newly hatched young to mature adults. Egg masses occur abundantly beneath stones in at least the upper 6 in. of the filter beds. These observations indicate that this species successfully carries on its life cycle in the trickling filter beds. The extremes of operational data for sewage going onto the filters for the two weeks preceding snail collections during May 1955 were:

Determination	Amount (ppm)
BOD	59 –131
Nitrogen:	
Total	24.4–24.8
Ammonia	13 –17.9
Chlorides	122 –128
DO	0

Dissolved oxygen in the filter effluent varied from 2.7 to 4.9 ppm. The pH

concentrations were not available for the stated period, but for the month of April they averaged about 7.1.

Natural Occurrence of Snails

Individuals of this species, *Physa integra*, are associated with sludge deposits resulting from the discharge of raw sewage into Ohio streams. They are also found in unpolluted stream reaches. From 50 to 100 specimens have been taken from a square foot of stream bed covered with sludge. The snails may occur as marginal animals in deep streams or rivers. In shallow streams they may be found living over the sludge-covered bottom under 1 to 6 in. of water. They have been taken in abundance in highly polluted reaches of such Ohio streams as the Mahoning, Great Miami, and Ottawa Rivers, and from Mill and Lytle Creeks. Baker (2) reports *Physa integra* is common in Michigan, New York, Ohio, Indiana, Minnesota, South Dakota, and Illinois.

Adult individuals of this snail may vary from 7 to 15 mm in length and from 4 to 9 mm in width. This snail, like other Physidae, is sinistral-coiled toward the left. It is a lung rather than a gill breather, and therefore not

FIGURE 2.—Snails associated with sewage treatment installations: (A) *Lymnaea humilis modicella;* (B) *Physa anatina;* (C) *Physa integra;* (D) *Physa halei;* (E) *Physa cubensis.*

typically dependent on dissolved oxygen. Thus, being capable of breathing atmospheric oxygen, it can live in septic areas of streams. Tooth (radula) tracks on the rock in trickling filter beds and on the surface of decomposing sludge in streams indicate that individuals feed on the biological film that covers such surfaces (3).

Occurrence at Sewage Treatment Plants

To assist operators in identifying snails, illustrations of selected kinds that have been reported as occurring in sewage treatment installations are presented in Figure 2.

Lohmeyer (4)(5) reports an unidentified Physid snail living in trickling filter beds in the sewage treatment plant of the University of Florida at Gainesville, Fla. Specimens were identified * as *Physa cubensis* (Figure 2E). This species is widely distributed in Florida and the West Indies. Lohmeyer (4) stated that individuals were "not quite ¼ in." in average length, and that individuals laid eggs in the filter beds.

Lohmeyer (5) reported that operational troubles due to snails were not experienced with standard-rate filters or with high-rate filters where settling had preceded recirculation before discharge to the filter. Some difficulties were reported with high-rate filters where snails became lodged in the mercury seal, resulting in friction which stopped the distributor. Constant cleaning of the mercury seal and occasional flooding and flushing of the filter have successfully controlled the snails.

Brown (6) studied the life cycle of *Physa anatina* (Figure 2B) living in trickling filters in a sewage treatment plant at Champaign-Urbana, Ill., during parts of the years 1932–35. No operational difficulties attributable to this snail species are recorded. Secondary settling tanks were also noted to be inhabited by *Physa anatina;* in addition 8 individuals of the snail, *Fossaria modicella* [= *Lymnaea humilis modicella* Say] (Figure 2A) were reported from these tanks. This species was not recorded as occurring in trickling filter beds. Referring to other records of snails reported from sewage treatment plants, Brown mentions that *Physa halei* (Figure 2D) has been reported from a Fort Worth, Tex., installation, but no operational difficulties resulting from the presence of this snail were noted.

The species *Physa integra* was found in one of two trickling filter plants at Hillsboro, Ohio. Each plant has two trickling filters. No difficulties that could be attributable to the mollusk have occurred at the plant where snails were found. Snails occupied the surface of the stone in both filters and were found under surface filter rock.

Conclusion

It may be pointed out that snails, in feeding on organism slimes, are thought to assist in keeping open the interstices between stones, thus lessening the chance of clogging and enhancing the flow through the trickling filters. In removing organic slimes, through feeding, they remove some small percentage of the BOD, as do various insect larvae. Snails can be looked upon as "crawling BOD removed," as *Psychoda* flies may be visualized as representing "flying BOD removed."

Acknowledgment

The cooperation of William J. Clench, Curator of Mollusks, Museum of Comparative Zoology, Harvard University, Cambridge, Mass., who supplied the snail specimens on which Figure 2 is based, is sincerely appreciated.

* By W. J. Clench, Curator of Mollusks, Museum of Comparative Zoology, Harvard University, Cambridge, Mass.

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CROP IRRIGATION WITH SEWAGE EFFLUENT*

By E. O. Dye

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All animals, including man, are dependent directly or indirectly upon plants for their food. Animals fed on mineral-deficient plants are poor themselves and the products that they furnish are of low quality. The problem, then, of plant and animal nutrition resolves itself into one of simply growing healthy crops. If sewage effluent is capable of expediting or encouraging this nutritional stability between soil and plant and animal then it has, indeed, a claim to agricultural priority without even considering its most significant merit, that of being a constant source of irrigation for arid soils.

Health Aspects and States' Utilization

A series of comprehensive studies by Rudolfs *et al.* (1)(2)(3)(4)(5)(6) covered the health aspects of utilizing sewage and sewage effluents for irrigation. Based in part on these studies the Texas State Health Department (7) concluded, relative to public health aspects, the following:

1. Raw sewage should not be used on any crop, and primary effluent should not be used on crops for human consumption. Complete treatment is preferred for feed and pasture crops used for animal consumption.

2. Although the use of treated sewage effluent is recommended for irrigation practices, the practice should be followed in such a way as to prevent the creation of a public health hazard, nuisance, or stream pollution.

3. If handled with reasonable care sewage effluent is not hazardous to the personnel. Cursory observations indicate that sewage plant operators as a group live as long if not longer than the average citizen.

Most western states concur with the Texas authorities and their convictions while some are more lenient. In many places (8) actual consumption of the effluent by cattle is common. California allows properly disinfected, treated sewage meeting bacterial standards equivalent to drinking water standards to be used for all crops. Other western states have similar regulations. Some have none. California is estimated to be using in excess of 50,000 acre-ft of sewage effluent per year for irrigation alone

* Presented at 1957 Annual Meeting, Arizona Sewage and Water Works Assn.; Mesa, Ariz.; Apr. 4–6, 1957.

—still a mere pittance when it is considered that Los Angeles alone channels one million acre-ft of effluent per year into the Pacific Ocean.

Soil and Crops

In addition to the states' feelings toward sewage quality, application, and desirability, there are other considerations for sewage irrigation, such as the soil and the crops.

A sure way for efficient plant feeding is to return all possible organic matter to the soil. This is quite the opposite of what is commonly practiced in Arizona and the west in general. Sewage effluent tends to offset this exhaustion of organic matter. Organic matter in itself, will open the feeding trails to the roots, provide food for healthy and friendly organisms, keep some root diseases in check, bring insoluble nutrients into solution, and improve soil structure in general. Sewage effluent, if it provided nothing more, would be worthy of consideration to partially replenish the organically depleted western soils which average less than 1 per cent organic matter or 20 tons per acre-ft when using 1.5 as the apparent specific gravity of the soil.

Plant nutrients of importance, such as the major elements of nitrogen, potassium, and phosphorus and the many minor elements, including sulfur, magnesium, calcium, iron, manganese, boron, zinc, copper, etc., are present to some degree in sewage effluents. Many of these nutrients are in soluble, immediately available forms. Soil structure and drainage determine, to a large extent, the utilization by the plant of these nutrients by determining the magnitude and vector of a root system. The balance of this paper will attempt to explain briefly plant and soil potentials in terms of water, organic matter, minerals, and nutrients if sewage effluent is the carrier. Specifically, all references will be to that effluent resulting from complete treatment at the activated sludge treatment plant, Tucson, Arizona. Little or no effort will be extended in itemizing important agricultural features such as soil preparation, soil conditioning and care, rates and techniques of effluent application, etc. These are problems for the farmer, groundskeeper, nurseryman, and all others using sewage effluent as a source of water.

The most productive and lucrative crops limited bionomically to be grown in the Tucson area and approved by the State Department of Public Health, Bureau of Sanitation, are, coincidentally, those ideal for sewage effluent employment. Cotton, small grains, permanent pasture, etc. thrive when given regular applications of sewage effluent.

Effluent Nutrient Value

A series of analyses was conducted, extending over a two-year period and covering major chemical considerations

TABLE I.—Two-Year Results of Tucson Sewage Effluent Analyses Including Agricultural Evaluations

Constituent	Amount (ppm)	Agricultural Value
Total solids	800–1,200	good
Susp. solids	10–40	—
Total N	16–20	good
Total P_2O_5	15–30	good
Mg	10–16	good
Total Fe	4–8	—
Cl	60–90	good
pH	7.3–7.5*	satisfactory
Alkalinity	180–280	insignificant
SO_4	120–180	good
HCO_3	220–342	—
CO_3	0	good
Hardness	175–250	medium
Ca + Mg	55–70	—
Ca + Mg	30–35†	poor to fair
Na + K	90–160	satisfactory to doubtful
Na	45–55†	satisfactory to doubtful
Na/Ca	2.5‡	satisfactory

* pH.
† Per cent of bases.
‡ Ratio.

TABLE II.—Average Results of Sewage Effluent Analyses at Field Discharge Point

Constituent	Average Amount (ppm)
Total solids	981
Total N	32
P_2O_5	70
K	22
Mg	16
Cl	100
pH	7.9*
SO_4	140
HCO_3	459
CO_2	0
Hardness	223
NO_3	5
Ca	70
Na	163
Na/Ca	2.7†

* pH.
† Ratio.

in the application of sewage effluent to soil and plants. Table I indicates the results, including agricultural evaluations of the various constituents.

These results indicated that the prospects for sewage effluent utilization were favorable. During the period of study only a small portion was being utilized for irrigation of field crops. Later a private firm contracted to employ all excess effluent. Much of this company's initial planning embraced not only anticipated flow rates and related factors but also these data accumulated by the analytical study. Delivery of effluent began in October 1955. Subsequent discussions suggested a need for effluent analysis at the site of distribution, since significant changes in composition could occur between final plant treatment and the point of application. The University of Arizona Agricultural Experiment Station carried on these tests with results as shown in Table II.

Discussion

Comparison shows little change in over-all concentrations although several hours and, in some instances, days have elapsed between sewage treatment and soil-effluent contact. The total soluble salts are within the range of ordinary tap water. The HCO_3 increase at the field is reflected in the pH change (7.4 to 7.9) and is influenced by algal growths. The metabolic processes of the algae as governed by temperature and sunlight intensity are responsible for the pH rise. This rise would be only temporary and is due to the residually acid nature of the algae on decomposition leading to the release of carbon dioxide plus an inherent tendency toward equilibrium. The slight rise in Na content suggests increased detergent use which may in turn explain the P_2O_5 rise as phosphates are present in many detergents. The total nitrogen increase can be explained by microbial nitrogen fixation in general and algal assimilation in particular. It may be said that this effluent may be handled as a mild liquid fertilizer. The soluble nitrogen and phosphorus contents, so important to western soils, are at a high level but in desirable ratios. The effluent is a fairly hard water with a sodium-calcium ratio indicative of subsequent minimum soil dispersion. This ratio may be regulated by the use of various soil conditioners such as gypsum, soil sulfur, etc. An average suspended solids content of 30 ppm is equivalent to spreading 81 lb of organic material on an acre with every acre-ft of effluent used and, with the photosynthetic build-up of algae in the detention and regulatory ponds, there should be a substantial increase in this figure.

Numerous facts are now available favoring the use of irrigation with sewage effluent. Sound sanitary principles are, of course, required in application. The increased yield of farm products is a major inducement.

In conclusion, sewage irrigation makes use of water (nutritional water as a rule) usually wasted, aids the economy of areas, reduces pollution loads on a water course (especially a

dry stream), and produces, with few adaptions, no hazards to operators and others.

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AUTOMATIC CHLORINE CONTROL

By Wayne Ransome

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During an extended period of applying chlorine to sewage with a manual visible vacuum chlorinator it became increasingly desirable to provide some kind of automatic regulator. Accordingly, a timing device was considered and installed, using convenient materials and equipment.

Figure 1 shows the chlorinator and power-driving arrangement. The unit control knob on the existing chlorinator was replaced with a bicycle sprocket. To this, a second smaller bicycle sprocket was connected by a chain to provide the driving mechanism. A reduction gear, with a ratio of 72:1, was connected to the small sprocket for further speed reduction. This reduction gear was located in a local junk yard, but any light-duty speed reducer of comparable ratio would be satisfactory. The speed reducer is powered through V-belt linkage by a ⅓-hp reversible motor.

For the chlorinator operation, limit switches were mounted on the chlorination frame, and adjustable stops were fastened to the feed-adjusting rack. The stops are slotted to allow the rack to stop in any position; after determining the required rate of feed, the stops are moved up or down to contact the limit switches so that the motor will shut off at the proper time. For equipment protection, a shear pin was installed on the pinion that drives the adjusting rack.

For time control a 24-hr time clock automatically adjusts the feed-adjusting rack to predetermined settings, in order to regulate the amount of chlorine with the known changes in volume of the treated effluents. For example, at 8:30 AM the rack is automatically moved up, increasing the amount of chlorine to coincide with the increase in sewage volume, and at 6:00 PM the

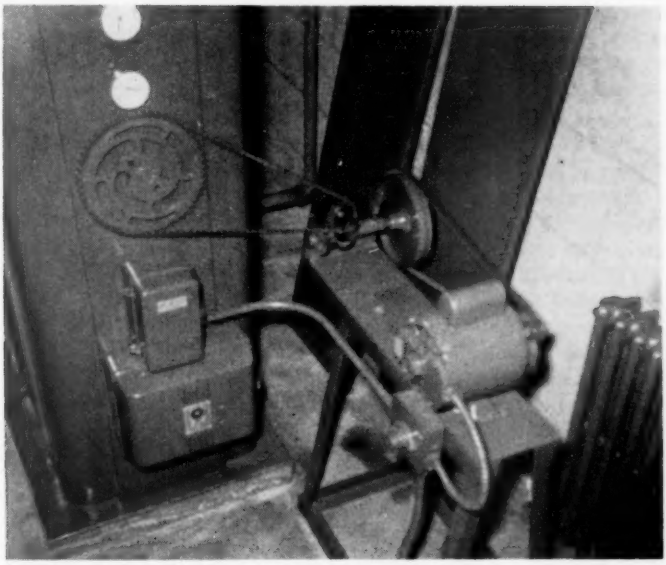

FIGURE 1.—Automatic chlorine control mechanism mounted on a manual visible vacuum chlorinator.

rack is moved down to stop at the feed rate required for the reduction in sewage volume.

The time clock is set by tabs so that adjustment may be made for control of feed for any hour of the day or night. The clock is wired through a line starter for reversal of the motor, and the mechanism is protected by a 6¼-amp fustat.

TREATMENT PLANT OPERATIONAL EXPERIENCES AT NEW ROCHELLE, NEW YORK *

By James M. Brown

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When the original sewer districts of Westchester County were formed, the communities of New Rochelle, Larchmont, and Pelham Manor located along the shore of Long Island Sound were not included because they already were operating their own municipal plants. However, the steady increase in population resulted in overloaded facilities and the need for either an extension to each of the existing plants or construction of a new plant to serve a sewer district which would embrace these communities. A study authorized by the Westchester County Board of Supervisors resulted in the formation of the New Rochelle Sewer District; the construction of a primary-type sewage treatment plant, a 9,900-ft, 54-in. concrete outfall sewer, and

* Presented at the Metropolitan Section Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Dec. 4, 1957.

trunk sewers to convey the wastes to the treatment plant. The plant, built at a cost of $3.8 million, was put in operation in August 1955.

Sludge Digestion

The digestion facilities at the New Rochelle plant consist of four fixed-cover digesters. Each tank is 65 ft in diameter, with a sidewater depth of 20.25 ft. Three draft tube sludge mixing units are used in each tank. The design loading is 3 cu ft per capita. The liquid level of each digester is controlled by annular rings, and supernatant can be withdrawn from three different elevations. The supernatant is returned to the influent end of the settling tanks.

Although all the intercepting sewers had not been completed, underflow from the settling tanks was pumped to the first digester commencing on August 23, 1955. Seed sludge was not available; therefore, it was fortunate that the digester could be started at a reduced load since the plant was not receiving a full flow of sewage. As the interceptors were completed the flow increased gradually until the digester was conditioned and well able to take the full load. The volatile acids increased to 3,200 ppm and the pH dropped to 5. Lime was added in small amounts but it is doubtful that it accomplished any more than to soothe the conscience of the operator. Nothing seemed to take the place of waiting because the first gas was burned 78 days after the digester was filled. After the first digester was operating satisfactorily, the other digesters were started using seed from the first tank.

Sludge Mixers

During the first 20 months of operation the digester sludge mixers were run from 1 to 2 hr per shift and little thought was given to the digester liquid level or to whether or not the mixers were working effectively. In June 1957, almost two years after initial operation, the digester manhole covers were removed. A layer of scum 5 to 6 ft thick was found covering the entire surface of the digester except for an area of 7 to 8 ft in diameter in the vicinity of each of the mixers. The scum was hard and dry, so much so that it was impossible to penetrate the mass with a stout pole. It was obvious that the mixers were not doing the job they were meant to do, either because they were not running long enough or because their zone of influence did not cover a sufficiently wide area.

With the help of the engineers from the manufacturer, a new pattern of operation was investigated. The mixers were run continually and reversed for a 30- to 45-min period every 8 hr for the purpose of flushing out the draft tubes. Even more important, the rings at the annular openings were removed to lower the liquid level in each digester. This increased the zone of influence, for when the depth of sludge and liquid above the draft tube impellers was too great the zone of influence of the mixer was small. This was because a sufficient volume of liquid to satisfy the capacity of the mixer was available almost immediately above the draft tube and approach velocities were high. By lowering the level of the tank liquid the mixers had to draw from a greater area, thus the zone of influence was increased. The result was that the mixers caused a skimming of the surface of the digester which pulled the grease and scum into the draft tube. This kept the scum wet and made it easier to move.

The surface elevation of the digester contents was the critical factor in the efficient operation of the mixers. Too high a level will decrease the zone of influence while too low a level will seriously reduce the capacity of the mixer. A submergence of 5 to 7 in. over the baffles seems to produce the

best skimming action. After operating for a period of six weeks, the scum had disappeared almost entirely. Less than 1 ft of soft wet scum was found on top of the digester.

The operating time of the mixers was reduced. They are now run for 4 hr on each shift, including 30 min in reverse before the start of each cycle. Control is provided by an automatic time clock. In the reverse position sludge is brought upwards from the bottom of the tank and is discharged along the top. This action tends to clean the draft tube as well as helps to keep the scum wet. In the forward position, scum is skimmed from the top of the liquid and discharged downwards. It is imperative that the proper liquid level be maintained; otherwise the mixers will not work efficiently. Subsequent inspections have shown the scum to be soft and less than a foot thick. The minimum time required for the operation of the mixers to keep the scum from building up must be determined by trial and error.

Supernatant

The continuous and efficient operation of the mixers kept the digesters so well mixed that a great number of solids were discharged in the supernatant. The settling tanks became black and acted as secondary digesters. To alleviate this septic condition in the settling tanks, a two-stage digestion system was instituted to keep the poor quality supernatant out of the settling tanks. Two of the digesters were set up as primary tanks and two as secondary tanks. The primary supernatant must be pumped to the secondary digesters because all of the digesters are at the same elevation and the supernatant from each digester returns to the clarifiers through a common line. Therefore gravity transfer was impossible.

The supernatant from the secondary digesters is clear since there is no need to run the secondary mixers, gas production is low, and the overflow from these digesters is discharged to the settling tanks. Sludge inventories show that the primary tanks have a fairly homogeneous mixture, ranging from 4½ per cent solids at the bottom of the tank to 2½ per cent at the lowest supernatant drawoff. The secondary digesters have a definite line of demarcation between solids and supernatant. The sludge from the bottom of the tank has a solids range from 8.5 to 9.7 per cent. Sludge can be transferred with maximum flexibility.

Sedimentation

Sludge Removal

The primary clarifiers are shallow tanks with an average depth of 7 ft. The sludge hoppers are equipped with cross collectors. However, a great deal of difficulty has been experienced with bridging of sludge in the sludge hoppers. This has been reduced somewhat by running the main flights for 1 hr only, immediately before pumping sludge from the tank. The cross flights are run only while pumping sludge from the particular tank. Apparently if the sludge is allowed to compact in the sludge hopper for long periods it will arch or bridge and the thick sludge cannot be withdrawn. It is not that the sludge is too thick to pump but rather on standing in the hopper the sludge arches, thereby supporting its own weight and holding itself away from the suction pipe so that only water is pumped.

Many things tend to aggravate this condition. A 2 to 1 slope on the sides of the sludge hoppers aids in sludge concentration and tends to discourage sludge bridging. Too wide a hopper tends to allow sludge to build up in the corners. The sludge suction pipe should be 8 in. in diameter and the hopper should not be cluttered with pipe supports or other structural features which tend to promote arching. If practical, a suction pipe on the

floor of the tank would be ideal. There has been little trouble from sludge arching in circular tanks, since they generally have no obstructions and the suction pipe is usually located on the floor. Sludge hoppers should be kept accessible so that they can be hosed down if necessary. If the sludge bridges, it is necessary to hose the hopper or break the bridge with a pole.

Sludge Pumping

Pumping sludge with a high solids content is a problem in plants of all sizes. During the first year of operation an average of 56,000 gpd of sludge was pumped. This is equal to 4,100 gpd per million gallons of sewage. More recently this has been reduced to about 35,000 gpd. This reduction can be attributed to a better understanding of the sludge bridging problems, more experienced sludge pumping to eliminate pumping sludge with a low solids content, and a reduction in the number of settling tanks in operation.

The procurement of a representative sample of sludge for solids analysis is a difficult task. The average solids content of the primary sludge was 2.3 per cent, as computed from the amount of sludge pumped and the solids removed. The pumping of excess water to the digesters not only wastes heat but also tends to wash the alkalinity from the digesting sludge. This involuntary elutriation has made it difficult to maintain alkalinity above 1,500 ppm. A pH of 6.6 and an alkalinity of 1,500 ppm is considered normal for the digesters at the New Rochelle plant. The only disadvantage foreseen in operating at this low pH is a lack of buffering material in the sludge which could prevent an upset in the digester from either an overload or from toxic material.

Overflow Rates

In spite of the importance of the sedimentation process and the long years of usage, little is known about the actual theory. There continues to be a need for practical work, particularly on the performance of shallow tanks.

TABLE I.—Settling Tank Efficiency, New Rochelle, N. Y.

Suspended Solids (ppm)		Overflow Rate (gal/sq ft/day)	Reduction (%)
Raw	Final		
180–225	65–75	1,000	60.8
—	60–65	750	61.7
—	50–55	400	62.8
140–180	62–68	1,000	58.7
—	60–65	750	60.2
—	55–63	400	61.5
100–140	—	1,000	—
—	50–55	750	56.2
—	45–53	400	56.4

The sedimentation tanks at the New Rochelle plant have an average depth of 7 ft. There are four tanks, each 156 by 41 ft. The design overflow rate is 600 gal/sq ft/day and the detention time is 2 hr at a flow of 15 mgd.

To accurately express the per cent efficiency of a settling tank (suspended solids reduction) it is necessary to know the concentration of the raw sewage. A tank which will give a 60 per cent efficiency with a suspended solids content of 225 ppm will not give the same per cent efficiency when the solids concentration drops to 125 ppm. Sewage entering the New Rochelle plant between 8 AM and 4 PM has a dry weather concentration of 180 to 225 ppm and an overflow rate of 1,000 gal/sq ft/day. At this solids concentration an efficiency of 60 per cent or better may be expected, whereas during the night shift when the solids concentration may drop to 100 ppm and the overflow rate decreases to 400 gal/sq ft/day the expected efficiency will be only 55 per cent. Table I shows the average efficiency based on more than 30 samples.

During 1956 the suspended solids content of the raw sewage was 103 ppm and that of the effluent 47 ppm.

The efficiency or per cent reduction in suspended solids was 54.4 per cent. The overflow rate during this period averaged 570 gal/sq ft/day and the detention time was 2.6 hr. Overflow rates of 960 gal/sq ft/day produced a suspended solids reduction of 55.8 per cent, based on a raw sewage suspended solids content of 156 ppm and a detention time of 1.3 hr.

There is no question that settling tank performance depends on a combination of overflow rate and detention time. If the solids in sewage settled without the aid of particle flocculation and coagulation, such as occurs with sand and inert materials, the overflow rate would be the only factor to consider. Fitch (1) states that where there is a considerable amount of flocculation and coagulation, as in the plain settling of sewage, the detention time must be considered. However, when a 55.8 per cent reduction in suspended solids can be obtained with a moderately weak sewage (156 ppm) and a detention time of 1.3 hr, it would not be expected that a further reduction in suspended solids would have been accomplished by increasing the depth of the tank, thereby increasing the detention time and keeping the overflow rate the same.

Each of the four settling tanks is equipped with 500 ft of longitudinal weir, giving a design rate of 7,500 gpd/ft of weir. Recently these weirs have been blocked off to produce an overflow rate of 42,000 gpd/ft of weir with no apparent decrease in tank efficiency. In rectangular tanks it would appear that the solids settle long before the effluent reaches the weirs. In small circular tanks and even in short rectangular tanks, emphasis should be placed on weir overflow rates. However, with rectangular tanks of moderate and large size a much higher loading can be permitted without impairment of the tank efficiency.

Sludge Dewatering

Digested sludge is withdrawn from the secondary digesters and filtered on an 8-ft by 8-ft coil-spring vacuum filter. The pump which pumps digested sludge from the digesters to the filter is located in the basement of the filter building about 17 ft below the level of sludge in the digester. The suction line is approximately 250 ft in length and at times difficulty has been experienced in pumping heavy sludge even with the high suction head. The sludge transfer pump was originally designed and located to pump sludge a short distance from the elutriation tank to the filter. Postponement of elutriation resulted in the pump being used to withdraw sludge from the digester. Sludge having a solids content of 8 to 10 per cent develops a high head loss.

A valuable tool that has been used at this plant in determining the filterability of sludge is the term "specific resistance" used by Coackley and Jones (2). The old Buchner funnel test has been of little help because the results cannot be duplicated. The time required before the cracking point depends on a number of variables such as the initial solids content, the volume filtered, the area of the surface, and the vacuum at which the work is carried out. Some time ago the concept of specific resistance was introduced, and the relationship between filtrate volume and time of filtration has a certain definite form. The term denotes the resistance of a unit weight of cake per unit area at a given pressure.

This test has been helpful in determining the effect that variations in chemical dosage have on filterability. Any change in the chemical dosage or sludge solids concentration is reflected by the value of the specific resistance. An increase in the specific resistance indicates a sludge that will be more difficult to filter while a decrease in

specific resistance indicates an increase in filterability.

The coil-spring filter has been operating most satisfactorily. The coagulant dosage has been 2.9 per cent ferric chloride and 6.1 per cent lime as CaO based on a dry solids basis. A high calcium lime is more desirable than is a high magnesium or dolomitic lime. The cost of filtration including labor but not depreciation of equipment or maintenance is $5.86 per 1,000 lb of dry solids or $3.90 per 1,000 gal of sludge filtered.

Even though an incinerator was provided, it has not been necessary to rely on its use for the disposal of the filter cake. The dewatered sludge is stockpiled and hauled away by a local nursery. The nurseryman mixes the sludge with an equal amount of a poor grade fill together with leaves. He believes that within a year the material will have composted to a useful top dressing. Large quantities of filter cake have been spread on the plant grounds preparatory to seeding.

References

1. Fitch, E. B., "The Significance of Detention in Sedimentation." THIS JOURNAL, **29**, 10, 1123 (Oct. 1957).
2. Coackley, P., and Jones, B. R. S., "Vacuum Sludge Filtration. I. Interpretation of Results by the Concept of Specific Resistance." THIS JOURNAL, **28**, 8, 963 (Aug. 1956).

OPERATIONAL REPORTS AND RECORDS *

By Louis A. Beck

Sanitary Engineer, Sunnyvale, Calif.

The principal duty of the sewage treatment plant operator is to run his plant so that it will fulfill its purpose, that of treating wastes so as not to cause nuisances or pollution of the receiving waters. To do only this, however, is not sufficient. The operator must (a) maintain the plant and equipment to protect the capital investment, (b) expend the funds allotted with the best combination of economy and effectiveness, (c) foster relations with the public so that the work of the plant may receive adequate support, and (d) keep records and make reports to show that the plant fulfills its function.

Although each of the preceding duties of the operator is important, the duty of maintaining records is the keystone for good plant operation. Operating records are kept: (a) as an aid to better operation, (b) as proof of the effectiveness of the operation, (c) as a journal for future reference, and (d) as an inspiration to the operator to excel previous performances. To avoid misinterpretation and confusion, records should be clear and concise and the information must be in common units. Uniformity and simplicity of units is necessary to assist others in making comparisons and analyses of the records. Only information that will be of use to the operator or his superiors should be included.

Value of Records

With the aid of records it is possible to determine the best time to take units out of service for maintenance or repair so normal operation will not be seriously interrupted. Trends noted in the records can serve as a guide to changes in operational procedures. This would be especially true at new plants where operational procedures are initially set up arbitrarily. As an example, at the Sunny-

* Presented at the 1957 Annual Meeting, California Sewage and Industrial Wastes Assn.; San Diego, Calif.; May 1–4, 1957.

vale, Calif., plant, all lights in the areas without windows were kept on 24 hr a day and all other lights were turned on at dusk and off at dawn. This was done because the lights were controlled from a central panel. It was thought that switches in the areas entered only occasionally would save electricity. For about three weeks the lights were turned on only when needed. The records kept during this period indicated a saving in electricity. Switches were installed in the areas entered only several times a day and approximately a 30 per cent saving in the cost of electricity was effected.

Basic Data

Records provide the basic data for proof of the efficiency of plant operation. A treatment plant is designed to remove a certain average percentage of settleable solids and BOD, depending on the type of units. The records will indicate whether or not the plant is obtaining the expected removal efficiency. It not, the records of operational procedures can be studied to determine what changes could increase the efficiency. Records will also indicate to the supervising personnel whether or not the operator is maintaining the plant at its top efficiency. At the Sunnyvale plant, the consumption of natural gas was reduced to a minimum by reviewing the records to determine which procedures utilized the sludge gas most effectively.

Reference

The use of records for future reference is of great importance. The operator who will review the records for comparisons of efficiency and operational procedures, and to anticipate changes in flows, will be able to plan his operations for maximum effectiveness. Supervisors frequently need to refer to records for cost data to prepare budgets and charges for sewer services. Design factors for plant expansion or a new plant can be determined by reviewing the records.

Incentive

Records may also serve as an inspiration to the operator to improve previous performances. At first this reason may not seem important. However, after some thought one can see that an operator might review the records and see that efficiency was low at some time and know better operation could be obtained. He might also make a comparison with a neighboring plant and strive to surpass its efficiency. Every operator can find items that need improving and when a new method is tried the records will show how good or bad it was.

Types of Reports

A treatment plant should prepare annual, monthly, and either daily or weekly reports. Each report summarizes and comments upon the data in the reports covering the preceding shorter periods. Pertinent data are added and comparisons are made with previous performances during similar periods.

Short Reports

There may be either a daily report or a shift log, depending on the size of the plant. In a shift log, the readings of all the meters and gauges are recorded by the operators at the end of every shift. Small plants may make the recordings only once a day for a daily report and large plants may summarize the shift logs into daily reports. The shift logs can be readily summarized into weekly reports which show all the more important items. Monthly reports summarize the daily or weekly reports and include special analyses, conditions of receiving waters, and other notes of particular interest concerning equipment or personnel.

Annual Report

The annual report is an accounting by the superintendent to his board and to the public of the performance, the

economy, and the needs of the treatment plant as based on the operation reports of the year. It contains a summary of the daily or monthly reports and a record of major changes in plant equipment, methods of operation and personnel, together with comments, comparisons, and recommendations.

Maintenance Report

There is a type of report other than operating reports that is essential to the economic operation of the treatment plant. This is the maintenance report, which assists the operators in the effective maintenance of all equipment. These reports aid the operator in determining that a piece of equipment is lubricated regularly and not in a hit-or-miss fashion. There should be a complete record of each item of equipment in the plant showing the required interval and type of lubricant and any other maintenance needed. The record should also indicate when the item was lubricated and by whom.

Time Required

It may seem that a considerable part of the operator's or supervisor's time should be devoted to record keeping. This, however, is not necessary. Records should not be kept for bulk or only for the sake of keeping records. Unused reports in a drawer are useless. Only those data that will be utilized should be recorded. In fact, engineers and designers should be warned against inclusion of unnecessary measuring equipment and supervisors should be warned of overly refined records. Plant supervision probably will be most successful when it combines expert practical observation of operations with record keeping, rather than being devoted to the amassing of analytical results and self-recorded measurements.

Report Form

The daily, weekly, monthly, and annual reports take various forms, depending on the needs and ingenuity of the operator. A monthly report may be a wall-sized chart that has all the flow data and analyses on one sheet. It might be a typewritten monthly or quarterly report that tells a complete story of the plant; even to giving a breakdown of the labor used. An annual report can be so well done that it analyzes the operation of the plant until there is little left to wonder about after the report is read.

Conclusion

Records aid in operation, show the efficiency of the plant, provide for future reference, and encourage the operator to excel previous preformance. If records are clear and concise and the operator uses them instead of being a slave to them, they will help him operate more efficiently and economically.

TIPS AND QUIPS

"High" Pollution

Pollution to a stream literally resulted in "polluted" fish in an Italian town recently. Wastes discharged from a winery resulted in fish in the receiving stream becoming so intoxicated that local residents were able to scoop them up for dinner. Considerable speculation can be made concerning the effects of the "pickled" fish on the consumers.

Dissolved Oxygen Determinations

In a series of papers from the Central Electricity Authority, London, on the microdetermination of dissolved oxygen in water, a self-testing and fully compensating analytical method is described. In this there is an ion exchange technique for circumventing interference from ferrous ion in the Winkler reaction. *Jour. Appl. Chem.* (London), **7**, 459 (Aug. 1957).

pH Control of Effluent

At an industrial manufacturing plant where acid rinses are used in metal operations the following system for neutralization of process effluent is described:

Before the acid rinse water is discharged into the sewer lines, it flows into a 6- by 3- by 2-ft retention tank installed behind the rinse tanks. Here pH is continuously detected by a stainless steel mounted dip-type pH electrode assembly, which translates pH into a proportional millivolt output. This electrode output is fed to an industrial-type continuous pH indicator, which amplifies the voltage and feeds it to a recorder-controller. The recorder-controller plots a 24-hr record of effluent pH and feeds a control signal to a valve-drive mechanism that regulates the addition of caustic soda to the rinse water in the retention tank. Mixers agitate the solution so that the caustic soda reagent is evenly distributed in the tank to adjust the pH of the final effluent to a predetermined level. The system not only maintains the effluent pH within certain limits, but also plots a graphic record of its performance.

Detailed information can be obtained from Leeds and Northrup Co., 444 North 16th St., Philadelphia, Pa.

Shippingport Begins Water Reactors

Nuclear operation of the pressurized water reactor (PWR) at Shippingport, Pa., began operation December 2, 1957. This date was significantly timed 15 years after the historic first chain reaction.

The Shippingport plant first produced electricity on December 18, 1957, and five days later operated successfully at its full design capacity of 68,000 kw. Of this total, 8,000 kw are required for operation of the plant; the remainder is for distribution to the Pittsburgh area over the Duquesne Light Company distribution system.

The Shippingport Atomic Power Station, with the PWR as its heat source, is the nation's first large-scale nuclear power plant to generate electricity for civilian purposes.

The primary purpose of the Shippingport plant is to advance the technology of pressurized water reactors, rather than to generate electricity at costs competitive with ordinary fuels, and it will not be operated to furnish continuous power with a maximum load factor. Development and operation of the plant will, however, provide information from which reliable cost estimates can ultimately be made for plants of this type.

The principal plant features specified in designing the pressurized water reactor were:

1. The plant was to have a net electrical output of 60,000 kw at 600 psi steam pressure.
2. The reactor was to be cooled by ordinary water at 2,000 psi.
3. The first core was to last for 3,000 hr at full power operation.
4. Refueling was to be accomplished with minimum shutdown period.
5. The reactor control system was to be as simple as possible.
6. Commercial equipment was to be used wherever practicable.
7. The cost of operating the plant was to be the minimum consistent with these requirements.

Over-all costs for the PWR plant, estimated late in January 1958, total $121,400,000, of which $98,400,000 represent Federal funds and $23,000,000 came from industry.

To point up the importance of the waste disposal aspects of the atomic energy industry it is significant to note that in the 1958 Nuclear Congress there were two half-day sessions devoted to radioactive waste treatment and disposal.

Reviews and Abstracts*

The Biological Assessment of Pollution in Birmingham Streams. By H. A. Hawkes. *Surveyor* (Brit.), **115**, 129 (Apr., 1956).

A method for evaluating the degree of pollution of streams, based upon a relatively simplified biological survey procedure, is presented. The method appears to offer a considerable advantage over some other methods in that it requires only approximate counting of the numbers of individuals of a given species collected. Far less time per station is required than is needed in the use of comparable methods based upon more elaborate counting procedures; yet conclusions of equal validity are produced.

Numerous examples, taken from river surveys in the vicinity of Birmingham (England), are presented.

M. C. Rand

Treatment of Trade Waste from British Celanese Factory at Derby. By G. Greene. *Surveyor* (Brit.), **116**, 228 (Mar., 1957).

Experiment on biological treatment of celanese (rayon) waste produced the following results:

1. When diluted with domestic sewage to 2.5 times the original volume, the waste could be treated on trickling filters with consistently good results.

2. Alternating double filtration gave slightly better performance than single filtration or recirculation.

3. In an activated sludge system, the waste caused bulking due to a large population of *Sphaerotilus natans*. Although the effluent itself was quite good, the bulking sludge could not be removed from it by settling.

M. C. Rand

Studies on the Biological Treatment of Sulfite Wastes. By E. Marczek and J. Zieliński. *Gaz. Woda i Tech. San.*, **31**, 6, 208 (June 1957).

From their experimental findings, the authors conclude that it is possible to develop an activated sludge from sulfite waste liquors and that these wastes could be treated by activated sludge or on trickling filters. The oxygen-consumed value of the waste was reduced by 43 to 50 per cent, and the 5-day BOD by 90 to 94 per cent, whereas the dissolved oxygen content was increased to above 4 mg/l. The biological flora changes both qualitatively as well as quantitatively in the various stages of treatment. Unaerated treated wastes spontaneously supported (without inoculation) microorganisms of the genus *Scenedesmus* or class *Ciliata* after eight weeks. In untreated wastes (maintained under identical conditions) no organisms developed.

Conrad P. Straub

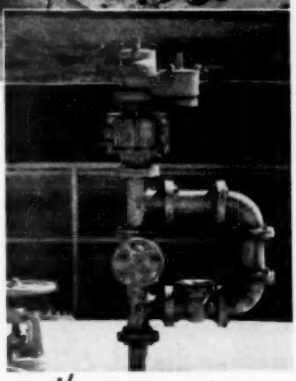
On the Methods Used for the Analysis of Contaminants in Surface Waters. By K. Michalski. *Gaz. Woda i Tech. San.*, **31**, 6, 217 (June 1957).

The role of chemical, physical, and biological (bacteriological and limnological) analyses for the determination of the extent of pollution in surface waters is discussed. The author concludes that none of these methods may be eliminated, but the extent to which each is used is determined on the basis of the information required. The analytical approach, as well as the interpretation of the results, should be in the hands of the limnologist and sanitary engineer, although they should be supported by specialists in the fields of industry, agriculture, fish culture, public health, etc.

Conrad P. Straub

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Photos courtesy Dorr-Oliver



SAFETY-ENGINEERED "Varec" SEWAGE EQUIPMENT at new Oxnard, California Sewage Plant

FOR SAFETY'S SAKE, on this recently started 6 MGD sewage treatment plant built for the City of Oxnard, California, contractor Fred J. Early and consulting engineers Currie Engineering chose the "Varec" Fig. 5800C Pressure Relief and Vacuum Breaker with Flame Arrester, and the Fig. 211A Back Pressure Check Valve.

Over the years, "Varec" equipment's record of safety, quality and dependability has been established in thousands of communities throughout the United States and Canada. For maximum protection in the control and regulation of volatile sewage gases, be sure—specify "Varec".

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S-16

Proceedings of Member Associations

FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

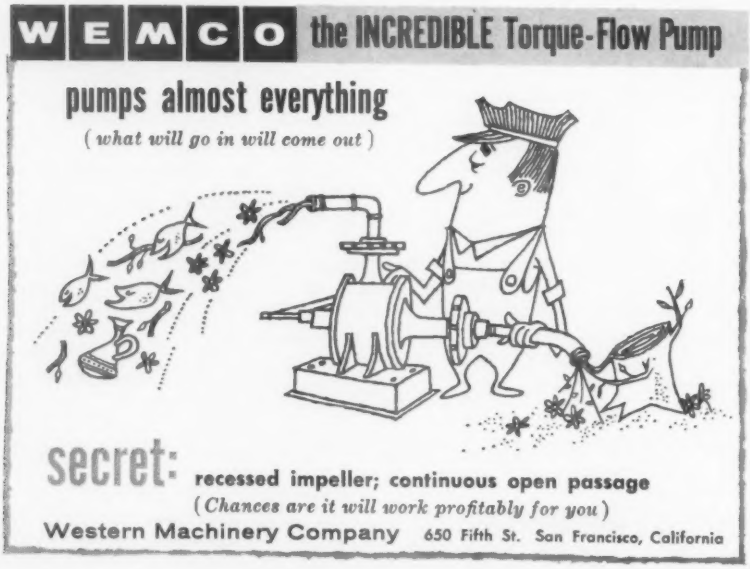
The 8th Annual Meeting of the Florida Sewage and Industrial Wastes Association was held at the Roosevelt Hotel, Jacksonville, Fla., on November 10–13, 1957, in conjunction with Florida Section, AWWA. Approximately 390 members and their guests were in attendance.

A highlight of the meeting was a panel discussion on the interpretation of sewage plant analysis, moderated by Clair N. Sawyer, Associate, Metcalf and Eddy, Boston, Mass.

Papers of special interest to sewage and industrial wastes were presented on the following topics: selling our services to the public, effect of sewage and industrial wastes on water quality and treatment, operation of an open digester in Florida, up-stream river surveys, a wet dust collector for use with rotary dryers, dust collection from phosphate drying operations, comparative cost data of dust collection equipment for phosphate rock drying operations, underground waste disposal, and effects of fertilization on receiving waters.

Emil C. Jensen, past president of the Federation of Sewage and Industrial Wastes Associations, delivered an address on, "The Challenge to our

(*Continued on page 238a*)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pumps almost everything
(what will go in will come out)
secret: recessed impeller; continuous open passage
(Chances are it will work profitably for you)
Western Machinery Company 650 Fifth St. San Francisco, California

Equipment and Supply Lines

Centralized Control System—A system for the remote control operation of any combination of pumps, valves, gates, etc. is described in Bulletin 240-P2A on "Synchro-Scan" supervisory control. The system was developed for distant control of remote units in water, sewage, and other facilities.—Builders-Providence, Inc., 345 Harris Ave., Providence 1, R. I.

Airlift Pumps—Bulletin No. 22S7548 describes the "Airopump," designed for low-lift pumping of sewage and industrial wastes with air. Detailed drawings, application curves, and other data are included.—Walker Process Equipment Inc., 840 North Russell Ave., Aurora, Ill.

Clay Pipe Joint Sealant—A clay pipe joint sealant for use with bituminous pre-molded joints is reported to have excellent sealing qualities under wet trench conditions.—Superior Clay Corp., Uhrichsville, Ohio.

Agitators, Grinders, Feeders, Dryers—Bulletin No. G3-B60 briefly describes a complete line of processing equipment, including agitators, dryers, feeders, filters, grinders, and pumps.—Denver Equipment Co., P. O. Box 5268, Denver 17, Colo.

Combustible Gas Analyzers—A well-prepared and illustrated booklet is available on combustible gas analyzers.—Mine Safety Appliances Co., 201 North Braddock Ave., Pittsburgh 8, Pa.

Floodlights—A high-powered floodlight designed for long-throw coverage of wide field areas is currently available.—Stonco Electric Products Co., 333 Monroe Ave., Kenilworth, N. J.

Activated Sludge—Catalog 6660 describes the operation and features of the "Hi-Cone" system of mechanical aeration of activated sludge. A draft tube and rotating vanes are used for reported increased effectiveness.—Yeomans Brothers Co., 1999 North Ruby St., Melrose Park, Ill.

Penetrating Oil—A special penetrating oil is described as containing rice oil and is useful as a metal pretreatment coating.—Guardian Chemical Products, Inc., 2110 Chartres St., Houston, Texas.

Sewer Pipe—Characteristics of extra-strength clay pipe are described in a 4-page technical bulletin.—Clay Sewer Pipe Assn., Inc., 311 High-Long Building, 5 East Long St., Columbus 15, Ohio.

Plastic Liner—A new 18-page illustrated booklet gives data on "Saraloy 898," a flexible thermoplastic, chemical-resistant lining for tanks, ducts, and large diameter pipes.—The Dow Chemical Co., Midland, Mich.

Air-Powered Sump Pump—A portable, air-powered sump pump provides easy pumping capacity for handling water, mud, sludge, or sewage. The pump can be lowered into the liquid; air is supplied by an air hose and liquid discharge is through a fire hose. Use of a portable air compressor, such as the "Pneumatractor" makes the pumping unit highly mobile.—Schramm, Inc., West Chester, Pa.

Operations Recorder—A vertical drum continuous recorder using an inkless stylus is available for recording the on-off operation of equipment. The stylus cuts through the wax-coated chart paper (6 by 14 in.), producing a colored line. Capacity is 400 linear inches.—Gorrell and Gorrell, Haworth, N. J.

Plastic Pipe—A dense plastic pipe made from polyethylene resin is described in Catalog No. 401. Application data for water and liquid lines are given.—Orangeburg Manufacturing Co., Inc., Orangeburg, N. Y.

"SpiroVortex"—Bulletin No. 7314 describes the principles of the Spiro-Vortex System which combines features of the high-rate filter with those of the activated sludge process.—Dorr-Oliver Inc., Barry Place, Stamford, Conn.

Organizations," at the opening session. At the banquet, Mr. Jensen presented the following awards:

The Bedell Award to Dr. David B. Smith, Gainesville, Fla.

The Hatfield Award to Clifford M. Courson, Tampa, Fla.

Officers elected for 1958 were as follows:

President: J. J. R. Bristow, Dunedin.
Vice-President: Sidney A. Berkowitz, Orlando.
Secretary-Treasurer: Ralph H. Baker, Jacksonville.

RALPH H. BAKER,
Secretary-Treasurer

CANADIAN INSTITUTE ON SEWAGE AND SANITATION

The 24th Annual Conference of the Canadian Institute on Sewage and Sanitation convened for a 3-day meeting, October 28–30, 1957, in the King Edward Hotel, Toronto, Ont. Approximately 700 people, including about 150 women, registered for a new record. The highest attendance in the past was about 525. The banquet and also the Metropolitan Toronto dinner attracted nearly 620 people.

The technical program covered a broad area of sewage, composting, and air pollution. Among papers of interest to those in the sewage and industrial wastes field were:

"Flotation in the Treatment of Sewage and Industrial Wastes," by E. Sherman Chase, Consulting Engineer, Boston, Mass.

"Meeting the Sewerage Requirements in Metro-Toronto," by Ross L. Clark, Commissioner of Works, Municipality of Metropolitan Toronto, Ont.

(*Continued on page 239a*)

The new "H" Series of Nagle Pumps, designed exclusively for the abusive pumping jobs of industry, is simplicity itself. Three types of water ends available to meet specific conditions, type "HF", "HC" and "HR" (shown). Various alloys used for water-end members depending upon corrosive, abrasive or high temperature conditions involved. Water-end can be rotated to any one of four discharge positions. Slippage seal adjustment takes only moments using a common wrench. Packing gland is readily accessible. Radial adjustment of shaft to insure concentricity through stuffing box is a matter of seconds. Various types of impellers available. Impellers readily accessible. Oil or grease lubrication is optional. Sizes from 1" to 10". Heads up to 250' or more. Capacities to 4,000 G.P.M. A "must" for those tough applications where ordinary pumps fail. Send for Bulletin "H".

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"Storm Sewer Design Practice," by Lucien L'Allier, Directory of Public Works, Montreal, Que.

"Joint Sewerage Works for Urban Areas Comprising a Number of Municipalities," by M. D. Stewart, Consulting Engineer, Toronto, Ont.

"Chlorine in Sewage Treatment and Stream Sanitation," by H. G. Likuski, Technical Service Supervisor, Chemicals Division, C.I.L. Montreal, Que.

"Guided Discussion: Combined vs. Separate Sewers," under the Chairmanship of C. G. R. Armstrong, Windsor, Ont.

The Bedell Award was presented to Gordon H. Baker, Industrial Commissioner and Project Engineer, North York Township, Willowdale, Ont., and the Hatfield Award went to Douglas J. Davidson, Superintendent, sewage treatment plant, Metropolitan Toronto, Ont.

Officers for the 1957–58 year are:

President: R. V. Anderson, Toronto, Ont.
Vice-President: J. F. MacLaren, Toronto, Ont.
Secretary-Treasurer: A. E. Berry, Toronto, Ont.

A. E. Berry
Secretary-Treasurer

WEST VIRGINIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 11th Annual Meeting of the West Virginia Sewage and Industrial Wastes Association was held in conjunction with the West Virginia Section of the AWWA, October 23–24, 1957, at the Hotel McClure, Wheeling, W. Va. Approximately 180 were in attendance at the 2-day session.

The technical program for the sewage and industrial wastes group was well balanced and appropriate for the meeting. Engineering aspects of coal

(*Continued on page 240a*)

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Q. What is the Discharge Louver?

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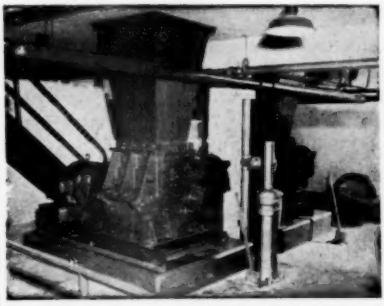

View of Twin Shredder Installation

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washery waste disposal were discussed, as were the operational aspects of this problem. A "Treatment Symposium" on the subject of chemical plant wastes and a municipality, was also a highlight. Pickle liquor problems were covered in another paper.

A breakfast for industrial wastes representatives was held one morning and was attended by about 20 people.

Officers were elected for 1957–58 as follows:

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Only 60 seconds from sewer to truck

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- Bypass street dumping!
- Bucket Contents dumped automatically!
- Two-man Bucket Machine Crew!
- Easier to operate! Simple to maintain!
- Streets kept free of sewer deposits!

Sewer deposits dumped automatically ...DIRECTLY INTO TRUCK!

No more unsanitary sewer deposits on the street.

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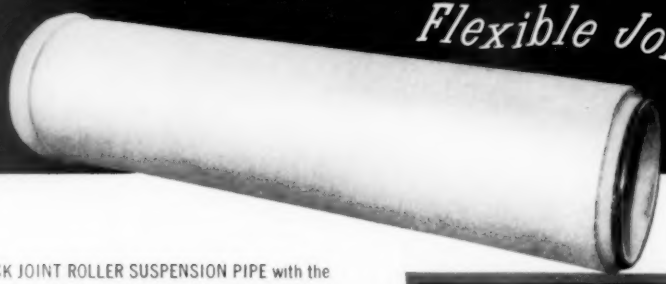
FOR YOUR MOST DEMANDING PROJECTS

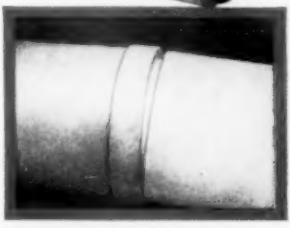
...the premium pipe with the Flexible Joint!



LOCK JOINT ROLLER SUSPENSION PIPE with the FLEXIBLE JOINT RUBBER GASKET is the ideal answer to installations requiring highest quality sewer or culvert pipe and maximum protection against ground water infiltration.

This pipe, produced in diameters from 12" to 72" and in standard lengths of eight feet is manufactured by an unique process which develops unusually strong, dense concrete, highly resistant to abrasion. Its joint ends, of almost machined accuracy, are particularly adaptable to the Lock Joint Flexible Joint Rubber Gasket.

This gasket gives effective relief from infiltration into the pipeline and permits the joint to be opened up to ¾" without endangering its tightness. This feature alone adds considerably to the ease and speed with which the line can be installed.



The "Flexible Joint" gasket permits ample deflection to accommodate normal ground settlement.

Lock Joint also produces conventional machine made and cast concrete sewer and culvert pipe ranging from 6" to 120" and upward in diameter. All Lock Joint Pipe may be designed to comply with A.S.T.M., state highway or individual specifications.

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